OUTSOURCING AND OUTFITTING PRACTICES

Implications for the Ministry of Defence Shipbuilding Programmes

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Preface

The United Kingdom's Ministry of Defence (MOD) is planning to produce two new aircraft carriers, called the Future Aircraft Carrier (CVF), to replace its three existing *Invincible*-class carriers. The two ships, which could be the largest warships ever constructed in the United Kingdom, are planned to enter the Royal Navy inventory in 2012 and 2015, respectively. After a lengthy competition between two contractors—BAE Systems and Thales UK—the MOD announced in January 2003 that the carriers would be designed and manufactured by an alliance involving BAE Systems, Thales UK, and the MOD. BAE Naval Ships and Thales UK have subsequently already formed the industrial Aircraft Carrier Team (ACT).

Because of the size of the new ships, the demands from other MOD programmes on the shipbuilding industrial base, and the complexity of the CVF programme, the MOD asked the RAND Corporation to perform an independent, objective, quantitative analysis to evaluate the cost, schedule, and technical risks of the competing contractor plans and to estimate the economic implications of using alternative manufacturing options.

Prior analysis identified a potential problem in the ability of the UK shipbuilding industrial base to meet the workload demands of the CVF programme in combination with the demands of other MOD programmes. The objective of the current phase of the research was to examine ways in which this problem could be overcome. The research was focused on two shipbuilding issues: advanced outfitting as a method to reduce the total CVF workload, and out-

sourcing as a method for the shipbuilders to increase the availability of labour. This report provides the results of our examination of advanced outfitting and outsourcing practices at various UK, US, EU,[1] and Asian shipyards. Based on the results of this examination, the authors provide a set of recommendations for the CVF programme.

This monograph is one of a set of three addressing related issues in UK shipbuilding. Funded by the MOD's Defence Procurement Agency (DPA), the three studies have the common goal of contributing to understanding better the warship-building industry within the United Kingdom and to improving management processes therein. The other two monographs answer the following specific questions:

- What metrics would keep DPA informed of progress towards completion of ship construction projects, and why do DPA-funded programmes tend to lag commercial projects in on-time completion rates? (MG-235-MOD)
- How do military and commercial shipbuilding differ, and what are the implications for diversifying the UK shipbuilding industry's customer base? (MG-236-MOD)

This report should be of special interest not only to the DPA but also to service and defence agency managers and policymakers involved in shipbuilding on both sides of the Atlantic. It should also be of interest to shipbuilding industrial executives in the United Kingdom.

This research was sponsored by the MOD and conducted within RAND Europe and the International Security and Defense Policy Center of the RAND National Security Research Division,

[1] For simplicity, throughout this report, the authors use the term 'European Union', or 'EU', to refer to those non-UK European shipbuilders surveyed (even though the United Kingdom is an EU member). Specifically, EU countries here consist of Denmark, Finland, France, Italy, the Netherlands, and Spain (see Table 1.1 for the full list of shipbuilders).

which conducts research for the US Department of Defense, allied foreign governments, the intelligence community, and foundations.

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Summary

The United Kingdom's Ministry of Defence (MOD) tasked the RAND Corporation to assess the outsourcing and outfitting practices of various countries' shipbuilders in an effort to provide recommendations for the ministry to better manage the production of two new aircraft carriers, as well as other new ships for the Royal Navy. The research effort finds that the shipbuilders in the United Kingdom should continue to use their current outsourcing practices as they build the new warships. However, these builders also should consider expanding these efforts by having subcontractors build crew cabins, meeting rooms, dining facilities, galleys, and other portions of the ship that could be supplied and installed as modules. Simultaneously, the shipbuilders should take advantage of outfitting practices used to build commercial vessels in other parts of Europe and Asia that allow the installation a variety of equipment—pipes, electrical gear, and heating and ventilation systems—at the earliest possible phase in the ships' production.

So concludes this study, performed between May and September 2003, of options open to the MOD as it manages the production of the Royal Navy's two new aircraft carriers. We suggest that by taking advantage of the outsourcing and construction practices used in other parts of Europe and Asia to build commercial vessels, the MOD will be able to produce the new carriers more effectively and efficiently, preserve the United Kingdom's military ship industrial base, and maintain the production schedules of other warships being built for the Royal Navy.

The Problem

The MOD is planning to produce two new aircraft carriers to replace the Royal Navy's three existing *Invincible*-class carriers. These Future Aircraft Carriers (CVFs) are planned to enter the Royal Navy inventory in 2012 and 2015, respectively. The CVFs could be the largest warships ever constructed in the United Kingdom.

The anticipated size of the CVF makes it unlikely that any single UK shipyard will be able to produce the vessel, given current production capacities. Instead, the MOD's plans call for major portions, or super blocks, of the carriers to be constructed in several shipyards, which upon completion would be transported to one shipyard for final assembly. Earlier RAND research noted that the near-simultaneous demands from several MOD programmes might seriously strain the available capacity of the UK shipbuilding industrial base.[1] In particular, there may not be a sufficient workforce at the various shipyards to meet the demands of the CVF, Astute, Type 45, and Military Afloat Reach and Sustainability (MARS) programmes.

What Was RAND Hired to Do About the Problem?

RAND's research analysed production options open to the MOD that will allow it to acquire the CVF in the most efficient and effective manner, preserve the United Kingdom's warship industrial base, and minimise disruptions in the schedules of other Royal Navy warships slated to be produced at the same time. It focused on the costs and utility of using *outsourcing* (i.e., subcontracting certain construction work to other firms or hiring temporary workers to augment in-house labour) to expand the workforce needed for CVF production, and of *advanced outfitting* (i.e., installing equipment foundations, pipes, power distribution systems, heating and ventilation systems, modular cabins, and other components during the early stages of con-

[1] *Evaluating Options for the CVF: Workload and Workforce Analysis,* unpublished RAND research, September 2002.

struction) to reduce the total workload demand of the programme. In particular, we explored and sought to

- understand the current outsourcing and advanced outfitting practices of UK shipbuilders
- compare and contrast these practices with those of US, EU,[2] and Asian shipbuilders
- provide recommendations to the CVF Integrated Project Team and other MOD shipbuilding programmes on how outsourcing and advanced outfitting could be used.

How Did RAND Study the Problem?

We reviewed past studies and related literature on outsourcing and outfitting, and created and conducted two surveys—one on outsourcing, the other on outfitting—of selected shipbuilders in the United Kingdom, United States, European Union, and Asia. In addition, our research team conducted follow-up interviews with managers of the shipbuilders who had been surveyed as well as other industry experts.

The survey on outsourcing practices requested both quantitative and qualitative data. We asked for data on outsourcing of functions associated with constructing the hull and other large structures (sand blasting, priming, painting, or fabricating) and with preparing and installing subsections of ships (e.g., machinery; piping; electrical power distribution systems; heating, ventilation, and air conditioning [HVAC] systems; accommodations; common areas; galleys; weapon systems). Upon receiving responses from the shipbuilders, we conducted on-site interviews with them to ensure our understanding of

[2] For simplicity, throughout this report, the authors use the term 'European Union', or 'EU', to refer to those non-UK European shipbuilders surveyed (even though the United Kingdom is an EU member). Specifically, EU countries here consist of Denmark, Finland, France, Italy, the Netherlands, and Spain (see Table 1.1 for the full list of shipbuilders).

the survey responses and to address more complex issues not covered by the survey questions.

The survey of outfitting practices was similar to its outsourcing survey. We asked various shipbuilders in the United Kingdom, United States, and European Union to provide quantitative and qualitative data on the level of advanced outfitting they typically use to accomplish various functional tasks at different stages of construction. The survey asked about how much outfitting the shipbuilders perform at each stage and the cost or time outfitting tasks take at the unit or block, grand block, and assembled ship stages of construction. We also posed questions about factors that limit the ability to do more advanced outfitting. Upon receiving the completed surveys, we conducted on-site visits and interviews with managers at each shipyard to ensure that we had completely understood their responses.

What Did RAND Find Out?

Outsourcing Practices

The survey found that shipyards employ two types of outsourcing: total and peak. *Total outsourcing* involves a shipbuilder subcontracting a complete functional task, such as electrical, HVAC, or painting, to an outside firm. In this case, the shipbuilder retains no in-house labour capability to perform the function, although the shipyard may provide facilities (e.g., painting sheds) or materials and equipment to the subcontractor. *Peak outsourcing* occurs when a shipbuilder uses a subcontractor or temporary labour to augment in-house capabilities during times of peak demands. This is done to reduce the shipyard workforce when demands decrease if faced with strict national labour policies limiting the ability to terminate workers, or to accelerate operations when schedules start to slip.

Figures S.1 and S.2 show the extent to which the shipbuilders we surveyed use each type of outsourcing. Figure S.1 shows the results for UK shipbuilders, and Figure S.2 for US and EU shipbuilders.

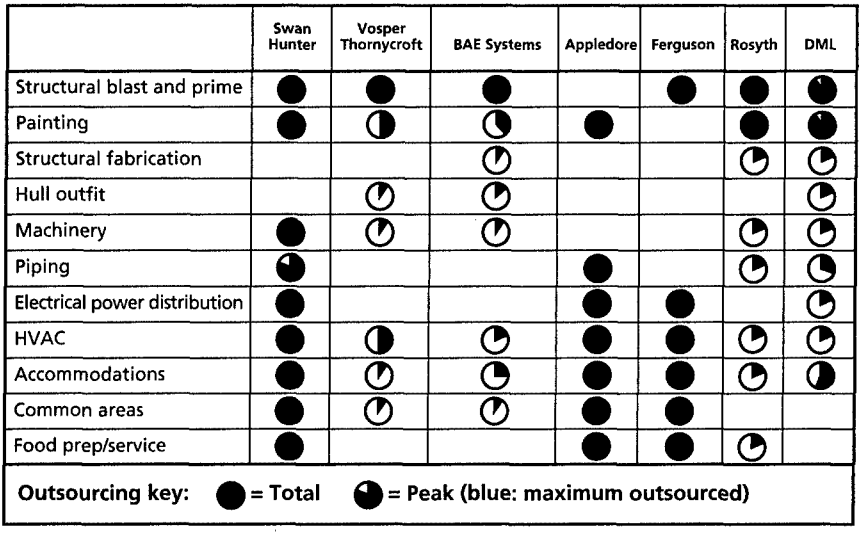
UK and US shipbuilders rely on subcontractors very little, either for total functional areas or for meeting peak demands. The majority of the EU shipyards we surveyed use total subcontracting extensively, maintaining in-house capabilities primarily in the structural areas. Total outsourcing is typically a key component of a long-term corporate strategy to focus a shipbuilder on core competencies while simplifying organisational structures and reducing overhead costs associated with facilities and capital investment. Shipbuilders also use peak subcontracting to augment their in-house workforce during periods of peak demands or when there are tight schedules to meet.

The survey also suggests that cost savings are not the primary reason shipbuilders use total or peak outsourcing. Although the cost of outsourcing may be slightly less than the cost of maintaining capabilities in-house, shipyards that use outsourcing do so mainly to control their workforce in the face of cyclical demands for certain skills. Tough labour policies in certain countries make it difficult and costly to adjust permanent workforce to meet varying demands. In addition to better workforce management, shipbuilders that use total outsourcing believe the quality of the end product is better with subcontractors who specialise in certain areas, such as accommodations.

Outfitting Practices

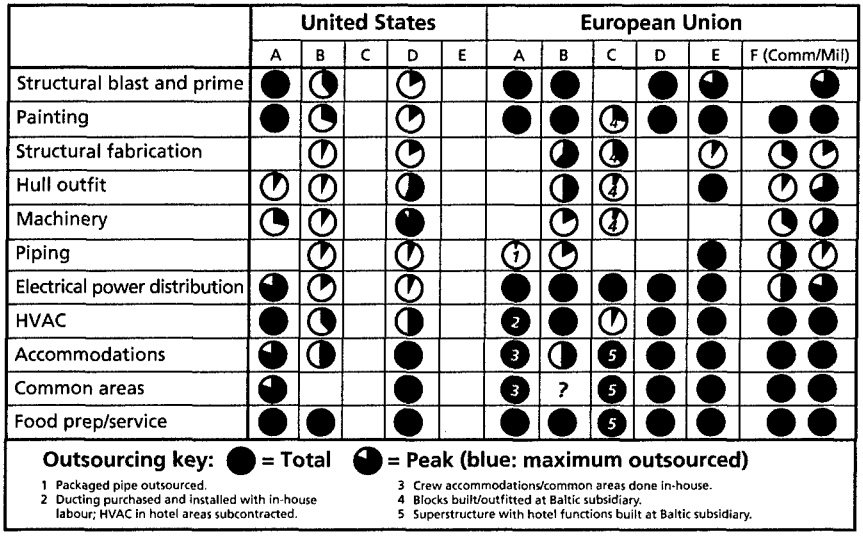
The degree to which shipyards use advanced outfitting is shown in Figure S.3. The figure depicts the results of RAND's survey of practices at different UK, US, and EU shipyards, with the vertical axis measuring the percentage of outfitting accomplished during early phases of construction. The points in the figure represent a specific shipyard's practices, which we have connected to represent ranges. While it shows our survey results only for the electrical power distribution tasks of installing cable, switchboards, and hangers, it is generally representative of outfitting practices associated with HVAC, piping, joinery, painting, and insulation.

Figure S.1
Use of Outsourcing at UK Shipyards



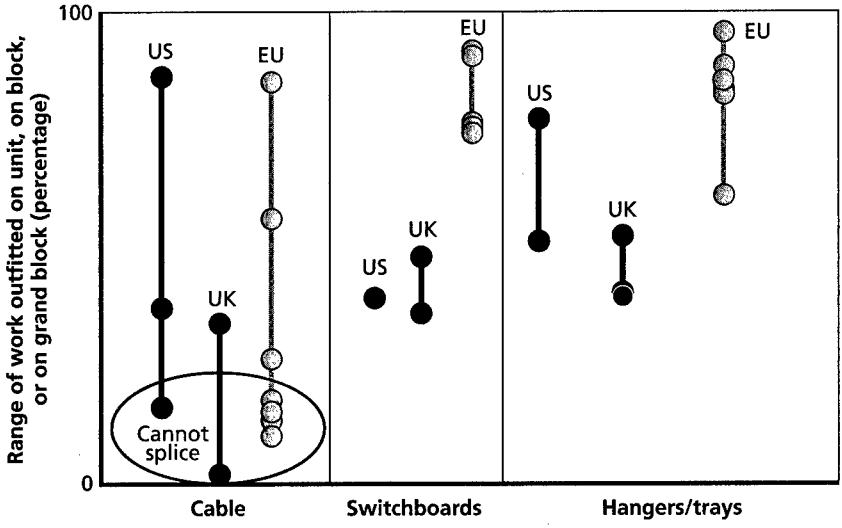
RAND *MG198-S.1*

Figure S.2
Use of Outsourcing by US and EU Shipbuilders



RAND *MG198-S.2*

Figure S.3
Advanced Outfitting Practices—Electrical Power Distribution



RAND *MG198-S.3*

The data suggest that UK shipbuilders accomplish lower levels of advanced outfitting than do most shipbuilders in the United States or European Union, not just for electrical power distribution tasks depicted but for a variety of other tasks. The figure also suggests that it is reasonable to plan for at least 80 percent advanced outfitting (i.e., before the work is to be done on the assembled ship). There are some exceptions, however. The oval in Figure S.3 represents shipyards where the customer will not permit cable splicing to be performed in advance. In such cases, an 80 percent advanced outfitting goal may not be appropriate.

What Policy Implications Flow from RAND's Findings?

Outsourcing

With respect to outsourcing, two general messages emerge from the research:

- One size does not fit all.
- Policymakers should not expect total outsourcing to result in significant cost savings.

The CVF and other MOD programmes should allow shipbuilders to follow their current total outsourcing practices. Having said that, the CVF and other MOD programmes should encourage shipyards to use subcontractors when demands exceed in-house capacity, as is likely to be the case over the next decade for UK shipbuilders. However, the current UK shipbuilding subcontractor base is very limited. Other than in the northeast area of the country, the historical lack of demand for subcontractors has resulted in a sparse supply of applicable subcontracting firms. Temporary labourers may also help to meet increased demands but may involve higher costs and lower productivity than do qualified subcontractors.

One area where the CVF programme should consider total outsourcing encompasses accommodation and personnel support functions, such as cabins, common areas (such as meeting rooms and dining facilities), and galleys. These 'hotel' functions are an area where many UK shipbuilders are starting to turn to subcontractors. For example, a subcontractor will build all the cabins for the Type 45 programme. It is also an area where a subcontractor can produce higher-quality products at lower costs than a shipyard.

Outfitting

With respect to outfitting, our research suggests that UK shipbuilders could do higher levels of advanced outfitting in pipe work, electrical, and HVAC functions. US and EU shipbuilders typically outfit their blocks and grand blocks to higher levels in these areas than the current practices of UK shipbuilders. Goals of 80 percent outfit at the super block stage are reasonable and achievable.

UK shipbuilders could achieve these higher levels by using more finished products—e.g., packaged machinery units, complex pipe assemblies, and modular cabins and galley—than they typically have in the past. Using such packaged products can also increase the

degree of outsourcing done by UK shipbuilders by having subcontractors produce the items.

By using more advanced outfitting, shipbuilders should be able to build the CVF with fewer labour hours. Although our survey suggests the labour savings are highly variable and depend on various factors, it is reasonable to assume that performing outfitting tasks at the block and grand block level requires 25 percent fewer labour hours than doing them on the completed ship (or super block) when it is in the dry dock.

Recommendations

In terms of outsourcing, our recommendations for the CVF and other MOD shipbuilding programmes are as follows:

- Identify as soon as possible the subcontractors that could participate in the shipbuilding programmes. (These may include non-UK firms.)
- Begin matching the appropriate subcontractors to the construction needs of specific shipyards.
- Involve any major subcontractors in the ship design process.
- Ensure that production designs are nearly complete before construction begins and that the shipyards have adequate manufacturing plans and processes that include the integration of any necessary subcontractors.

For advanced outfitting, our recommendations are as follows:

- Encourage shipyards to develop manufacturing plans that strive to produce super blocks that are at least 80 percent outfitted before they are sent to the assembly shipyard.
- Involve all shipyards in the design process and encourage the sharing of information on advanced outfitting practices.

- Ensure production designs are nearly complete before construction begins and that the necessary equipment and materials are available in a timely fashion to facilitate advanced outfitting.

Acknowledgements

This research would not have been accomplished without the support and encouragement of Ali Baghaei, leader of the CVF Integrated Project Team (IPT). Many other individuals of the MOD and the IPT provided their time, knowledge, and assistance during the course of the research. In particular, we thank David Farmer, Robin Boulby, and Neil Mounty.

The cooperation and assistance of the various shipyards was essential to gathering the data and information contained in the report. Listing the names of the many individuals at all the shipyards would fill several pages. We graciously thank them all for the time and insights they shared with us.

Two individuals deserve special recognition. Philip Koenig of the US Office of Naval Research's Asian field office provided valuable information on the outsourcing and outfitting practices of Japanese and South Korean shipbuilders. He also offered many careful and constructive comments on earlier drafts of this report. Thomas Lamb of the University of Michigan's Department of Naval Architecture and Marine Engineering facilitated our interactions with the European shipyards and shared with us his broad knowledge of shipbuilding practices. He too provided valuable inputs to earlier drafts of the report.

We are also appreciative of Laurent Deschamps of SPAR Associates Inc. for sharing his vast knowledge of outsourcing and outfitting practices. At RAND, Kim Curry provided valuable research assistance, especially in organising and summarising the wide range of

data we received. Rajkumar Raman provided a very thoughtful review of an earlier draft of the report that helped strengthen the overall presentation of the material.

These individuals helped us with factual information and suggested important considerations for the research. We, however, are solely responsible for the interpretation of this information and the judgement and conclusions drawn. And, of course, we alone are responsible for any errors.

Abbreviations

CVF	Future Aircraft Carrier
D&M	Demonstration and Manufacture
DML	Devonport Management Limited
FSL	Fleet Support Limited
HVAC	heating, ventilation, and air conditioning
IPT	Integrated Project Team
LSD(A)	Landing Ship Dock (Auxiliary)
MARS	Military Afloat Reach and Sustainability
MOD	Ministry of Defence (UK)
NASSCO	National Steel and Shipbuilding Company
NEMOC	North East Marine and Offshore Cluster
SEMTA	Science, Engineering, and Manufacturing Technologies Alliance

CHAPTER ONE

Introduction

Background

The United Kingdom's Ministry of Defence (MOD) is planning to produce two new aircraft carriers to replace its three existing *Invincible*-class carriers. These Future Aircraft Carriers (CVFs) are planned to enter the Royal Navy inventory in 2012 and 2015, respectively. The CVFs could be the largest warships ever constructed in the United Kingdom.

Originally, two contractors competed for the Demonstration and Manufacture (D&M) of the future carriers—BAE Systems and Thales UK. Each contractor submitted an initial D&M plan to the MOD in 2001. These plans described the proposed manufacturing scheme, including how and where the ships could be constructed. Both companies updated their initial plans and prepared final submissions for the CVF design effort. In January 2003, the MOD announced the alliance approach involving BAE Systems, Thales UK, and the MOD to design and build the two carriers.[1] The Thales UK design was taken forward.

The anticipated size of the future carriers is believed to be beyond the current production capability of any single UK shipyard.

[1] The industrial alliance between BAE Naval Ships and Thales UK is formally known as the Aircraft Carrier Team (ACT).

Current plans call for major portions, or super blocks, of the carriers to be constructed in several shipyards and then transported to one shipyard for final assembly. However, depending on the final size of the ships, there may be no UK shipyards with current facilities (dry docks, cranes, production facilities, etc.) suitable for the assembly of the ships. In reality, construction of any of the larger portions of the ship will constitute a major shipbuilding effort in itself for any UK shipyard. In addition to the problem of facilities and capacities within the current shipbuilding industrial base, plans for the construction of the two carriers must consider how other current and future shipbuilding programmes, both military and commercial, will affect the availability of workers and facilities. Finally, given the potential need to coordinate activities at several shipyards in the construction of the carriers, centralised design teams, tools, and software must also be considered.

Because of the complexity of the CVF programme, the MOD asked the RAND Corporation to provide independent, objective, quantitative analyses of the cost, schedule, and technical risks of the competing companies' proposals and to estimate the economic consequences of alternative manufacturing options. This research was intended to provide the information needed by the MOD to obtain value for money and to ensure a healthy shipbuilding industrial base for current and future programmes.

Research Objectives

During prior analysis of the CVF programme, RAND identified a potential problem with the available capacity of the UK shipbuilding industrial base in light of the near-simultaneous demands from several MOD programmes.[2] The prime concern was the availability of sufficient workforce at the various shipyards to meet the demands of the CVF, Astute, Type 45, and Military Afloat Reach and Sustain-

[2] *Evaluating Options for the CVF: Workload and Workforce Analysis*, unpublished RAND research, September 2002.

ability (MARS) programmes. The research recommended a close examination of outsourcing as a method to potentially expand the workforce needed for CVF construction and advanced outfitting as a way to reduce the total workload demand of the programme.

Given the recommendations of the prior analysis, the objective of the current research phase is to

- understand the current outsourcing and advanced outfitting practices of UK shipbuilders
- compare and contrast these practices with those of US, EU,[3] and Asian shipbuilders
- provide recommendations to the CVF Integrated Project Team (IPT) and other MOD shipbuilding programmes on how outsourcing and advanced outfitting could be used.

Research Approach

To fully address the research issues, we created separate survey forms and sent them to a variety of UK, US, and EU shipyards. Their responses allowed us to understand how they used outsourcing and advanced outfitting in constructing ships.[4] These surveys requested both quantitative and qualitative data from the various shipbuilders. Upon receiving responses to the surveys, we conducted follow-up visits to ensure that we had fully understood the shipyards' responses and to address more complex issues that were not adequately covered by the survey questions.

Table 1.1 shows the shipyards that provided responses to our surveys. In addition to the UK, US, and EU shipyards, we obtained

[3] For simplicity, throughout this report, the authors use the term 'European Union', or 'EU', to refer to those non-UK European shipbuilders surveyed (even though the United Kingdom is an EU member). Specifically, EU countries here consist of Denmark, Finland, France, Italy, the Netherlands, and Spain (see Table 1.1 for the full list of shipbuilders).

[4] The outsourcing and advanced outfitting surveys are reproduced in Appendixes A and B, respectively.

various information and data from individuals knowledgeable of shipbuilding practices in Asia.

Although we collected a wide range of very useful data on outsourcing and advanced outfitting practices, some shipbuilders had difficulties responding to some of the quantitative questions, as the following examples show:

- Some did not collect or record data in the manner that was needed to adequately respond to the questions. This was especially true for the relative costs associated with using subcontractors versus keeping the work in-house and the hours devoted to various types of outfitting during different stages of the construction process.
- Some had problems interpreting the intent of certain questions. For example, a few included material and equipment costs as outsourced expenses when what we were really interested in were labour costs.

Table 1.1
Shipbuilders Who Responded to the RAND Surveys

UK Shipbuilders	US Shipbuilders	EU Shipbuilders
Appledore[a]	Bath Iron Works	Chantiers de l'Atlantique (France)
BAE Systems	Electric Boat	Fincantieri (Italy)
Devonport Management Ltd.	Kvaerner Philadelphia	IZAR (Spain)
Ferguson	National Steel and Shipbuilding Company	Kvaerner Masa (Finland)
Rosyth	Northrop Grumman Ship Systems	Odense (Denmark)
Swan Hunter		Royal Schelde (The Netherlands)
Vosper Thornycroft		

[a]This builder did not complete the survey but provided information during an on-site visit.

- Some provided averages across the various types of ships that they constructed (e.g., both military and commercial ships or cruise ships and ferries) as opposed to separate values for each type of ship produced.
- Still others answered questions with subjective data or data based on future plans.

Although it was difficult obtaining information when the shipbuilders' systems did not collect the required data in the format needed, we were able to correct most of the initial survey problems during the on-site visits or with follow-up data submissions.

Organisation of This Report

The remainder of the report is organised in two main chapters. Chapter Two addresses outsourcing. It provides a brief overview and some basic definitions; summarises the results of the survey responses from the UK, US, and EU shipbuilders; describes the cost implications of outsourcing; and provides an overview of the availability of subcontracting firms and temporary labour in the United Kingdom. The chapter ends with recommendations and implications for the CVF programme. Chapter Three follows a similar format for advanced outfitting. It first provides some background and basic definitions, and summarises the results from the survey responses. It then describes the impact on construction workload of outfitting at various stages of the construction process and provides recommendations and implications for the CVF programme. Last, Appendix A presents the outsourcing survey sent to the shipbuilders, while Appendix B shows the advanced outfitting system survey.

CHAPTER TWO

Shipbuilding Outsourcing Practices and Implications for the CVF

Outsourcing occurs when shipbuilders subcontract certain work during ship construction to other firms, either other shipbuilders or non-shipbuilding organisations. We have broadened that definition for this research to include situations in which shipbuilders hire temporary labour to augment their in-house labour force.

Potential Advantages of Outsourcing in the CVF Programme

Outsourcing may offer several advantages to the shipbuilders involved in the CVF programme and to the programme itself. These potential advantages include the following:

- **A way to alleviate shipbuilder workforce shortfalls.** Our prior analysis of the CVF programme identified potential problems with the UK shipbuilding industrial base meeting the near-simultaneous demands of several MOD programmes scheduled to commence in the near future. In the next few years, the CVFs, Type 45 destroyers, Astute submarines, and MARS auxiliary ships will all begin their construction phases. These assets will place demands on a UK shipbuilding industrial base that has contracted over the past decade as a result of declining orders in both the commercial and military ship markets. Ship-

yards have closed (e.g., Harland & Wolff and Cammell Laird), and the shipbuilding workforce has dropped from a level of approximately 11,000 production employees in 1992 to approximately 7,000 in 2002. Outsourcing may be needed to provide the total labour capacity to meet future demands.

- **Reduced CVF construction cost.** Many books and articles on the subject suggest outsourcing can reduce the total costs of building a ship. These savings are a result of reduced overheads, potentially lower wage rates, lower costs associated with the hiring and dismissal of shipyard workers to meet cyclic demands, and improved quality that can lead to fewer man-hours and less rework associated with certain construction tasks. One objective of this research is to quantify the cost effects for UK shipbuilders that use a greater degree of outsourcing.
- **Reduced need for new capital investments.** CVF work may result in the need for modification of existing facilities or construction of new facilities at the various shipyards involved in the programme. The use of subcontracts may negate the need for these facility enhancements, thereby reducing capital investment costs.
- **Uniform quality of ship systems on the CVF super blocks.** Because of the size of the CVFs, no one shipyard has the facilities and workforce to build a complete ship. Current build plans call for several large sections, or super blocks, of the ship to be built in various shipyards and then transported to one shipyard for final assembly and test. Each super block will be self-contained in terms of electrical power distribution; piping systems; heating, ventilation, and air conditioning (HVAC) systems; and accommodations. Common subcontracting firms used by all three shipyards may provide uniform systems for the various super blocks.
- **Compatibility between the systems that go across super blocks.** Some outfitting work will be done on the assembled ship as opposed to being done on each super block. For example, the splicing of cable is often prohibited on military and commercial ships. In those cases, cable is installed after the final assembly of

all the blocks and modules. Also, crew accommodations and other 'hotel' functions such as food service, laundry, and waste disposal are installed on assembled commercial ships to eliminate potential damage during the construction of the blocks. Again, using a subcontractor for those systems that go across the super blocks may ensure uniform quality.

RAND's Five Research Objectives

To more fully understand the potential advantages and disadvantages of a greater degree of outsourcing by UK shipbuilders, our research sought to answer the following questions:

- To what degree, and in what areas, do UK shipbuilders currently use outsourcing?
- How do UK outsourcing practices compare with those of shipbuilders in the United States, European Union, and Asia?
- Are data available to measure the cost impact of outsourcing?
- Is there an adequate supplier base in the United Kingdom to support greater levels of outsourcing?
- What are the overall implications to the CVF programme and to other MOD shipbuilding programmes?

RAND's Survey of Shipbuilders

To help address these issues, we composed a set of survey questions that requested both quantitative and qualitative data from various shipbuilders.[1] We asked for data on outsourcing in several functional areas, including structural blast and prime, painting, structural fabrication, hull outfitting, machinery, piping, electrical power distribution, HVAC, accommodations, common areas, food preparation and service, and combat systems. Upon receiving responses from the shipbuilders, we conducted on-site interviews to ensure our under-

[1] The outsourcing survey is provided in Appendix A.

standing of the survey responses had been correct and to address more complex issues not covered by the survey questions. This section provides a summary of what we learned from the surveys and the site visits.

Shipyards Employ Two Types of Outsourcing

Based on the responses from various shipbuilders, outsourcing seems to be used in two very different ways: total outsourcing and peak outsourcing.

Total outsourcing involves a shipbuilder subcontracting a complete functional task, such as electrical, HVAC, or painting, to an outside firm. In this case, the shipbuilder retains no in-house labour capability to perform the function, although the shipyard may provide facilities (such as painting sheds) or materials and equipment to the subcontractor. The subcontractors may be turnkey, in which they provide the design, the materials and equipment, and perform all installation,[2] or partial turnkey, in which the shipbuilder may provide some combination of the design, facilities, and materials and equipment.[3]

Peak outsourcing occurs when a shipbuilder uses a subcontractor or temporary labour to augment in-house capabilities during times of peak demands or to accelerate operations when schedules start to slip. Many shipyards also use peak outsourcing to adjust their workforces when demands decrease in light of strict national labour policies that restrict the termination of permanent employees. The subcontractors may work at the shipyard alongside shipyard employees or at their own site and provide the final product to the shipbuilder. An example of the latter is having an outside firm build portions of the ship structure and send them to the shipbuilder for integration into the final

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[2] An example is the use of turnkey subcontracting for the common areas on cruise ships. Most cruise-ship builders will provide dimensions and utility hook-ups for such areas as theatres and casinos and require the subcontractor to do all design and construction within those areas.

[3] An example of partial turnkey subcontracting is for painting. A shipbuilder will often provide the facilities, since the painting must be done at the shipyard and requires permanent structures, and the paint and rely on the subcontractor to apply the paint.

ship. Peak outsourcing may be used for all the types of ships a shipyard builds or for only certain types of ships in the shipbuilder's product line.

Total Outsourcing: Use at UK Shipyards

Figure 2.1 shows those functional areas where the United Kingdom's three largest shipbuilders—Swan Hunter, Vosper Thornycroft, and BAE Systems[4]—use total outsourcing (the cells with blue circles). Of the three builders, only Swan Hunter uses subcontractors over a wide range of functional tasks. Basically, Swan Hunter concentrates on steel fabrication and pipe work and relies on subcontractors for most other functions. The company best fits what is often referred to as the 'European model'. As we will discuss later in this section, Swan Hunter is part of the North East Marine and Offshore Cluster (NEMOC), a partnership of 15 companies in the northeast of England with ties in the shipbuilding and offshore industries. The companies within this consortium provide a broad range of functional skills to Swan Hunter.

Typically, Vosper Thornycroft and BAE Systems use total outsourcing for only structural blast and prime of plates and profiles. In fact, BAE Systems, Vosper Thornycroft, and Swan Hunter all rely on subcontractors for both these types of work. Typically, the shipyards procure steel that has been shot-blasted and primed at the factory. Specialised subcontractors also perform blast and prime on structural units at the shipyard. Except for structural blast and prime, both Vosper Thornycroft and BAE Systems maintain a wide range of in-house functional capabilities.

Although as a general rule Vosper Thornycroft and BAE Systems use total outsourcing for only structural blast and prime work, there are exceptions for specific projects. For example, Vosper

[4] BAE Systems operates three shipyards, Barrow-in-Furness in the northwest of England (BAE Systems Submarines) and Govan and Scotstoun on the Clyde in Scotland (BAE Systems Naval Ships). Barrow primarily builds submarines, although it has built some surface ships in recent years. Govan was formerly owned by the Kvaerner group and has built both military and commercial ships. Scotstoun, formerly the Yarrow shipyard, builds surface combatants, including ships for foreign military sales.

Thornycroft has used a subcontractor for HVAC work on some of its projects, and BAE Systems has used subcontractors for electrical power distribution, HVAC, and accommodations for its Landing Ship Dock (Auxiliary) (LSD[A]) project. This latter example was due to the nature of the product (a hybrid military and commercial ship), the practices of the lead shipyard (Swan Hunter used its established subcontractors that could readily support the follow ships built at Govan), and the historical commercial shipbuilding practices at Govan.[5]

Peak Outsourcing: Use at UK Shipyards

Figure 2.2 shows how the United Kingdom's three largest shipbuilders use peak outsourcing (the shaded proportion of the circles). These

Figure 2.1
Total Outsourcing—UK Large Construction Shipyards

	Swan Hunter	Vosper Thornycroft	BAE Systems
Structural blast and prime	●	●	●
Painting	●		
Structural fabrication			
Hull outfit			
Machinery	●		
Piping			
Electrical power distribution	●		
HVAC	●		
Accommodations	●		
Common areas	●		
Food prep/service	●		

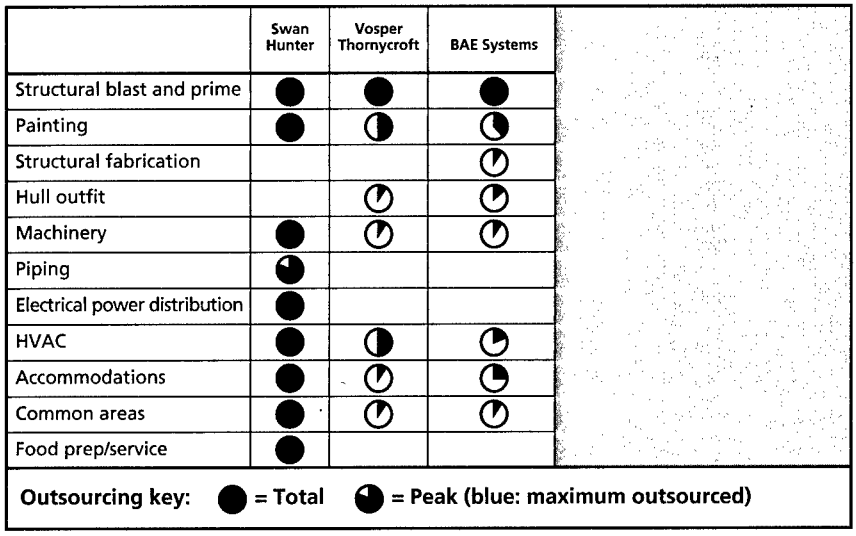
Outsourcing key: ● = Total

RAND *MG198-2.1*

[5] Before takeover by BAE, Govan was previously owned by Kvaerner and primarily built commercial ships. In line with the practices of its parent company, Govan turned to subcontractors for those functional areas that could not sustain uniform demands on the workforce.

builders tend to rely almost exclusively on in-house labour to meet any peak workload demands. However, there are some exceptions to this general rule. Vosper Thornycroft used some temporary workers to meet recent increased demands because of the need to deliver three Offshore Patrol Vessels in a short period. This was an anomaly; Vosper Thornycroft would rather hire permanent workers than use temporary labour when an increase in workload is sustained over a long period as opposed to being a short-term effect. The company views the cost of training and additional supervision associated with temporary labour as being lost once the temporary hire leaves the firm versus being an 'investment' for new permanent employees. BAE Systems has, at times, used subcontractors when overload situations occur in their shipyards. For example, the company used Harland and Wolff to build tank units for its auxiliary oiler project.

Figure 2.2
Total and Peak Outsourcing—UK Large Construction Shipyards

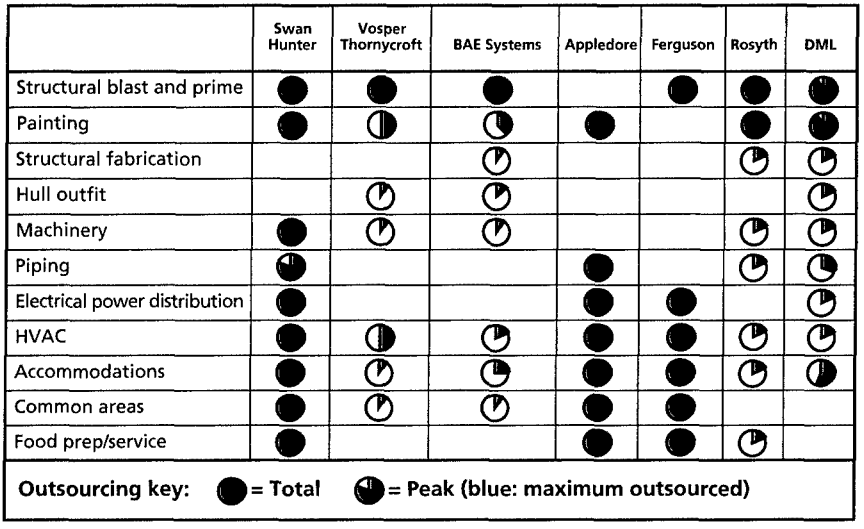


RAND *MG198-2.2*

Figure 2.3 completes the outsourcing picture for the UK shipbuilding industrial base by adding the outsourcing practices at two small shipyards, Appledore and Ferguson, and two repair shipyards, Rosyth and Devonport Management Limited (DML). Appledore[6] and Ferguson resemble Swan Hunter in that they primarily concentrate on steel fabrication and rely on subcontractors for most other functions. Note, however, that some of the subcontractors are wholly owned subsidiaries of the shipbuilders. For example, the joinery companies that support Appledore and Ferguson are each subsidiaries of the shipyards.[7] It is debatable whether these types of subsidiaries should be considered as subcontractors or in-house capabilities.

As would be expected of shipyards that concentrate in repair activities, both Rosyth and DML do very little structural fabrication.

Figure 2.3
Use of Outsourcing at UK Shipyards



RAND *MG198-2.3*

[6] Appledore subcontracts pipe spools but does the installation with in-house labour.

[7] The original pipe subcontractor for Ferguson went out of business. Ferguson then decided to bring pipe work capabilities back in-house.

They rely almost exclusively on in-house labour for the majority of their functional tasks. The exception is Rosyth's total outsourcing of both structural blast and prime and painting. DML retains some in-house capabilities in these areas in order to manage its workforce but relies mostly on subcontractors. DML and Rosyth use subcontractors extensively in other functional areas to manage peak workload demands. Also, at the time of our on-site visit, DML was considering outsourcing its joinery work.

Outsourcing Practices in the United States, European Union, and Asia

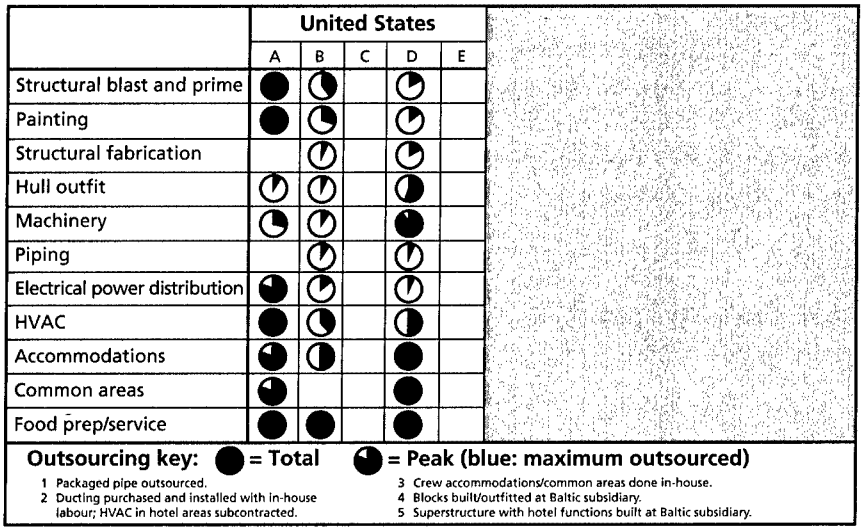
Total and Peak Outsourcing in US and EU Shipyards

Figure 2.4 shows the use of total and peak outsourcing by US shipbuilders.[8] In general, US shipbuilders, like Vosper Thornycroft and BAE Systems, are vertically integrated, relying very little on subcontractors. Shipyard A builds only commercial ships and relies more on subcontractors than the other US shipyards that build primarily military ships. Shipyard A plans to outsource to an even higher degree in the future when a more robust vendor base becomes available in the United States. Shipyard D, the only other shipbuilder that uses total outsourcing to any degree, builds both commercial and military auxiliary ships. Shipyards C and E do not use subcontractors at all.

The use of subcontractors for peak outsourcing varies across US shipyards. The new Kvaerner shipyard in Philadelphia uses subcontractors to meet peak demands for accommodations and electrical power distribution work. This practice is primarily for acquiring technical skills that are unavailable in their permanent workforce. Northrop Grumman's two closely located shipyards in the Gulf Coast area

[8] Throughout the report, we use codes for the US and EU shipbuilders, rather than showing the specific shipyards, to safeguard any business-sensitive data.

Figure 2.4
Use of Outsourcing by US Shipbuilders

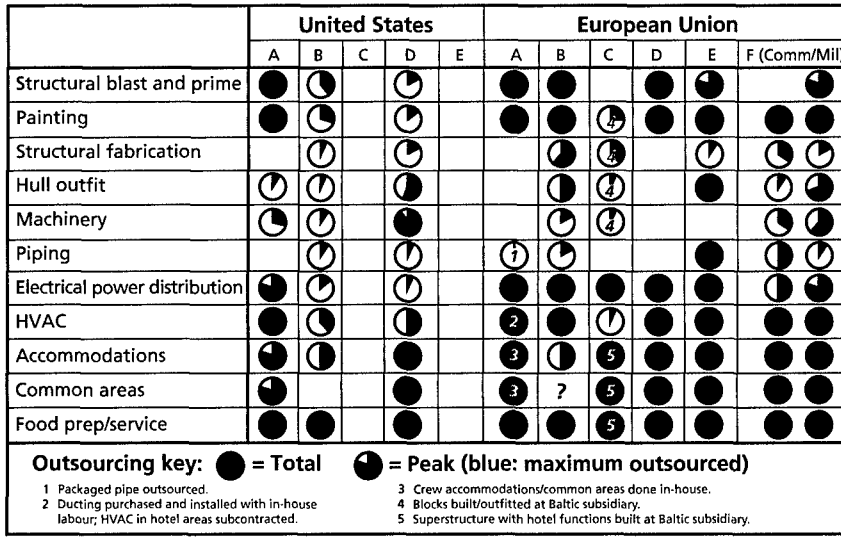


RAND *MG198-2.4*

will shift workers to meet peak demands at any one of the yards. The National Steel and Shipbuilding Company (NASSCO), which primarily builds commercial cargo ships and military auxiliary vessels, will use temporary workers or subcontractors to meet peak demands.

Figure 2.5 shows those functional areas where EU shipbuilders use outsourcing. EU shipyards use subcontractors to a much higher degree than either UK or US shipbuilders. Primarily, EU shipbuilders concentrate on steel fabrication and rely on subcontractors for most other shipbuilding functions. This applies for both shipyards that build military ships and those that assemble commercial ships. We address the reasons why the EU shipbuilders use subcontractors to a large degree later in this report.

Figure 2.5
Use of Outsourcing by US and EU Shipbuilders



RAND *MG198-2.5*

Total and Peak Outsourcing in Japanese and South Korean Shipyards[9]

Outsourcing practices in Japanese shipbuilding vary according to industry sector. The Japanese shipbuilding industry is divided among six major shipbuilders and 18 medium-sized shipbuilders.[10] The majors are components of large, diversified heavy industry conglom-

[9] Insights into outsourcing practices by Japanese and South Korean shipbuilders were provided by Philip Koenig, Associate Director from Industrial Economics and Technology in the U.S. Office of Naval Research's Asian field office, and Thomas Lamb, Head of the Marine Systems Division of the University of Michigan's Transportation Research Institute. An informative article on Japanese outsourcing practices is Koenig, Narita, and Baba (2001).

[10] The six large shipbuilders are IHI Marine United Incorporated, Kawasaki Shipbuilding Corporation, Mitsubishi Heavy Industries Limited, Mitsui Engineering and Shipbuilding Company Limited, Universal Shipbuilding Corporation, and Sumitomo Heavy Industries Limited. They currently account for approximately half of Japan's total ship production. The medium-sized shipbuilders approach the large shipbuilders in total output and would be considered large shipbuilders in the United Kingdom or the European Union.

erates, and most have two facilities. Also, only the majors build naval warships. The major shipbuilders are substantially vertically integrated, even to the point of producing large components such as main propulsion, low-speed diesel engines. At most, they totally outsource certain parts of the accommodations outfit. They use peak outsourcing to level the demands within their shipyards and to manage their workforce. However, because of their high throughput, flexible labour force, and shop management ability, Japanese shipbuilders experience relatively few in-yard labour demand fluctuations when compared with their overseas counterparts. During peak demand periods, a major Japanese shipbuilder will spread work over its facilities or may outsource blocks to smaller shipyards or specialised companies. In the general course of shipbuilding operations, major shipbuilders rely heavily on in-yard subcontract labour, mostly in production, to provide management with the flexibility that the traditional Japanese labour employment system does not accommodate. Recently, for example, about 30 percent of Mitsui's shipbuilding workforce was comprised of in-yard subcontractors.

Medium-sized Japanese shipbuilders are less vertically integrated than the six majors. They evolved this structure primarily to minimise fixed costs. These medium-sized shipbuilders outsource to a much higher level than their major counterparts, especially in design and research and development functions. At least one of these builders, Shin Kurushima, has established a subsidiary company to handle all pipe work for its multiple shipyards.

Japan's medium-sized shipbuilders do use subcontractors to a high degree to manage peak workloads. Typically, 30 to 50 percent of the workforce for this size of shipbuilder will be made up of subcontractors.

The South Korean shipbuilders[11] are vertically integrated, maintaining more functional capabilities in-house than other leading shipbuilders. They rely little on total outsourcing in their shipbuilding processes. This is partly a result of their very large scale of operations.

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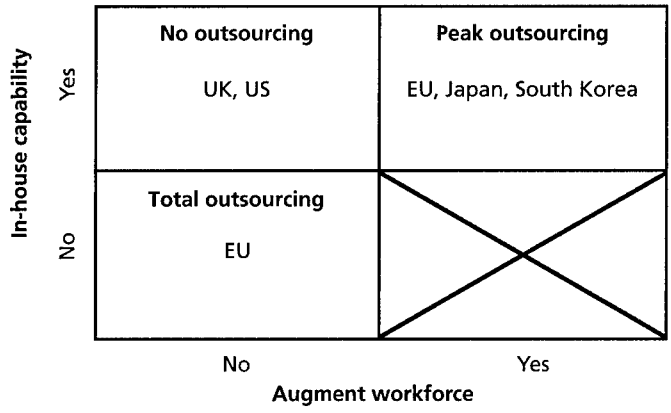
[11] South Korea has four very large shipbuilders—Hyundai, Daewoo, Samsung, and Hanjin —that account for 95 percent of its total ship production.

For example, in diesel main engines, the volume required by Hyundai's shipyard likely outstrips the available capacity of any potential supplier. In addition, there was little existing supplier infrastructure when the Korean shipbuilding industry began its period of high growth in the 1970s. This left the shipbuilders with little choice but to develop and retain in-house the various functions required to build ships. Regarding peak outsourcing, South Korean practice is similar to that of the Japanese shipbuilders. Recently, for example, in strong market conditions, in-yard subcontractors made up about 45 percent of Samsung's shipyard workforce.

Summary Comparison of UK, US, EU, and Asian Outsourcing Practices

Figure 2.6 summarises the outsourcing practices of UK, US, EU, and Asian shipbuilders. The two dimensions in the figure represent whether a shipbuilder retains in-house capability for a wide range of functions (i.e., does not use total outsourcing to a large degree) and whether it uses outsourcing to augment its workforce during times of increased demands.

Figure 2.6
Summary of Outsourcing Practices



RAND *MG198-2.6*

The UK and US shipbuilders rely on subcontractors very little, either for total functional areas or for meeting peak demands. Although the use of subcontractors or temporary workers to meet peak demands is more an exception than the rule for the majority of UK and US shipbuilders, there are some cases that reflect differently. In the United Kingdom, for example, Swan Hunter uses total outsourcing for several functions: maintaining in-house capabilities for structural fabrication, hull outfitting, and some pipe work. In the United States, Kvaerner Philadelphia uses subcontractors in a similar manner.

The majority of the EU shipyards we surveyed use total subcontracting extensively, maintaining in-house capabilities primarily in the structural areas. They also use peak subcontracting to augment their in-house workforce during periods of peak demands or when there are tight schedules to meet.

Japanese and South Korean shipbuilders use total outsourcing for a few select functions such as accommodations and steel castings. They rely heavily on peak outsourcing, especially the medium-sized shipbuilders, to augment their in-house workforce during peak demand periods.

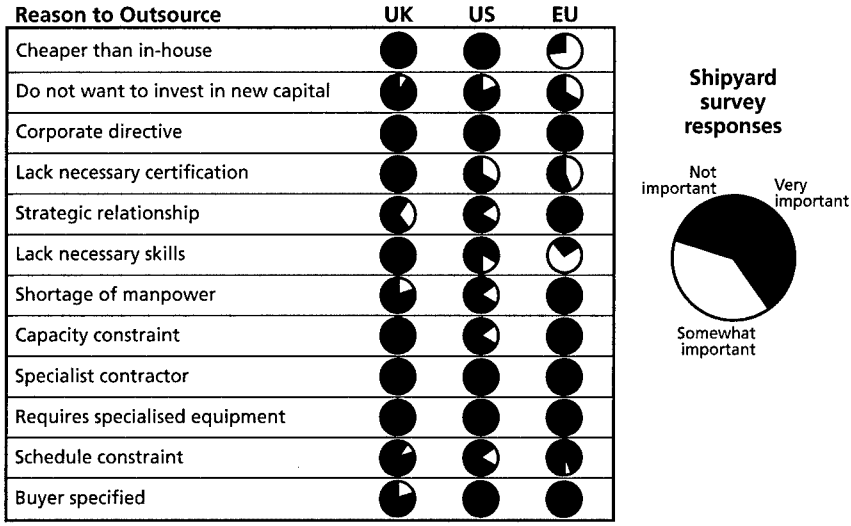
For peak outsourcing, the shipyards we surveyed tend to favour subcontractors over hiring temporary employees for several reasons. Subcontractors typically have a trained workforce, highly skilled in their area of expertise. They also have their own equipment and may even build units, such as cabins and galleys, in their own facilities. This reduces the training demands associated with temporary employees and may even reduce overhead costs at the shipyards. The productivity of the subcontractors is higher than that of temporary employees, and the work is of better quality. For these reasons, using subcontractors is usually a more cost-effective solution for peak outsourcing than hiring temporary employees. But subcontractors must be effectively integrated with the shipyard workforce to ensure smooth and efficient production processes.

Reasons Why Shipbuilders Do and Do Not Outsource

In our survey, we asked the various shipbuilders why they used outsourcing. We provided a list of reasons and asked them to characterise whether each reason was *very important*, *somewhat important*, or *not important* in their outsourcing decision process. We show the reasons and the summary responses across the shipyards in Figure 2.7.

The reasons for outsourcing varied significantly between the EU shipyards and the US and UK shipyards. US and UK shipyards uniformly stated that they outsourced to reduce costs. This proved interesting because there is so little outsourcing done in US and UK shipyards. The other two reasons that the shipbuilders gave for outsourcing were the lack of necessary skills and, for the US shipyards, the need to follow a corporate directive. These responses were primarily from Swan Hunter and Kvaerner Philadelphia for the areas where they use total outsourcing.

Figure 2.7
Reasons Why Shipyards Outsource



RAND *MG198-2.7*

EU shipyards relayed very different reasons to outsource. Although they view cost as somewhat important, they uniformly stated that their outsourcing practices are a result of corporate directives. Schedule constraints and the lack of necessary numbers or skills in their workforce were the other reasons cited most often.

Most EU shipbuilders use outsourcing to meet peak demands, thereby allowing them to more effectively manage the levels of their permanent workforce. Countries such as Germany, Italy, Spain, and the Netherlands have strict labour policies regarding the ability to terminate workers and the requirement to make substantial payments to workers let go because of a lack of work. To avoid these large severance payments, shipbuilders constrain the hiring of new employees. In some cases, the outsourcing of complete functional areas evolves from the gradual reduction of in-house capabilities and the increased use of subcontractors.

At EU and Asian shipyards, commercial ship contracts typically carry heavy penalties for late delivery. This is because the ship owner has often made plans for future cruises or cargo deliveries based on the delivery date specified in the contract. Late deliveries result in lost revenues and ill will among the customers of the ship owner. For the shipbuilders, therefore, 'schedule is king', and every measure is taken to ensure that ships are delivered on time. If schedules slip, however, the shipbuilders use additional workers, typically temporary hires or subcontractors, to bring the schedule back in line. The military shipbuilders of the United States and the United Kingdom, and even in some other European countries, do not feel the equivalent pressures or the need to bring more resources to bear when schedules start to slip.

EU shipyards also view outsourcing as a way to simplify their organisational structures and to reduce the overhead costs associated with facilities and capital equipment. At the same time, EU shipbuilders believe that turning certain functional areas over to subcontractors increases the quality of the end product. This is especially true for the hotel-like areas (e.g., the cabins, restaurants, theatres, casinos) of modern cruise ships. The specialised contractors that provide those areas typically also support the hotel and resort industries.

Shipyards also communicated several reasons why they do not outsource. The primary reason cited was that they already had established capabilities in-house, including facilities, equipment, and employees, and believed it was less expensive to use these capabilities than to turn to subcontractors. We discuss this more fully later in the report.

Although US and UK shipbuilders have more freedom in hiring and terminating their employees than do builders in other European countries, they typically believe that their unions would cause significant problems if temporary workers were used on any consistent basis. Kvaerner Philadelphia and NASSCO do not have the same union related problems as other US shipbuilders.

Other reasons why US and UK shipbuilders do not outsource relate to the security concerns surrounding military ships; specialised equipment, especially weapon systems, on most military ships; and the lack of an adequate supplier base in their geographical region. Even the new shipyard in Philadelphia, which closely follows the practices in the European Union, has experienced problems finding local subcontractors and has had to use non-US providers for certain equipment and services.

The Cost Impact of Outsourcing

As mentioned above, EU shipbuilders do not use total outsourcing as a way to reduce costs. They rely on subcontractors primarily as a method to manage their workforce in the face of tough national labour policies. They also see total outsourcing as a way to simplify their overhead structure and obtain higher-quality products. EU shipbuilders stated that the use of subcontractors for major construction functions has reduced costs by, at most, 10 percent.

Some shipbuilders, however, do use peak workload outsourcing to control costs. They believe it is less costly to hire temporary labour or a subcontractor to help meet peak demands than it is to bring on full-time employees. However, for the builders of commercial ships, capacity and schedule constraints drive the use of outsourcing to meet

peak workload demands more than any potential cost savings. Shipbuilders also mentioned the lack of productivity of temporary hires compared with full-time employees or even qualified subcontractors as well as the increased difficulty in managing temporary workers.

At times, shipbuilders meet peak workload demands and shave costs by sending structural work to shipyards in Eastern Europe, especially those yards that are members of their overall corporate structure. At least two EU shipbuilders we interviewed sent structural work, including complete structural hulls and deckhouses, to Eastern European shipyards because of their substantially lower wage rates there, both for employees and subcontractors.

There are two extremes among shipyards when considering the 'make versus buy' decisions of either keeping work in-house or using subcontractors for total outsourcing.

On the one hand, there are shipyards that have been building ships for decades, if not centuries, and have built up over time their in-house capabilities, including the workforce, facilities, and manufacturing equipment. When considering total outsourcing, they typically conclude that their in-house capabilities are less expensive to use than turning functions over to a subcontractor. Most US and UK shipyards fit this paradigm.

At the other extreme are 'new' shipyards that are just starting operations. Examples include the Kvaerner shipyard in Philadelphia and to a large degree Swan Hunter in the United Kingdom.[12] They typically do not have the workforce, facilities, or manufacturing equipment for certain functions and view subcontractors as a lower-cost alternative to establishing the capability in-house.

Recent decisions on the use of subcontractors by Northrop Grumman Newport News Shipbuilding highlight how a shipyard can reach different conclusions for different functions. Using a structured decision process, Newport News decided to outsource all motor

[12] Swan Hunter is not, in the purest sense, a 'new' shipyard. Its roots go back to the mid-1800s. However, the shipyard went into receivership in the latter part of the 20th century and lay idle for some time. It was resurrected as a shipbuilder in the early 1990s but started with no workforce, and outdated facilities and manufacturing equipment.

repair work, based on cost and the availability of suitable suppliers.[13] However, the shipbuilder decided to keep switchboard and panel work in-house, although there was some probability that costs would be lower if the work were outsourced. Newport News based its decision on the uncertainty of the overall cost impact and the desire to keep the switchboard and panel work as a core company competency.

Adequacy of the UK Supplier Base to Support Greater Levels of Outsourcing

MOD also asked RAND to examine as a part of this study the extent of the shipbuilding subcontracting base across the United Kingdom. This is an important issue because, should the UK shipbuilders need additional labour to support the future shipbuilding programme, subcontracting portions of the work to specialist firms may provide an opportunity to make up some of the labour shortfall.

UK Shipbuilding Subcontracting Base

Overall, the extent of the United Kingdom's shipbuilding subcontracting base is very limited. With the exception of Swan Hunter in the northeast, the majority of warship builders perform most of their core shipbuilding activities in-house. Since there is little demand for subcontracted labour or services, such firms do not tend to be located in the warship building centres in Scotland, the northwest, or the southeast. Even among the services that are subcontracted, some of them may still be part of the larger shipbuilding group. For example, Ferguson subcontracts all its joinery work to a fully owned subsidiary. This firm has premises on Ferguson's site but has the ability to undertake work for other organisations as well.

When selecting subcontractors, all of the UK warship builders and repairers use competition as one of their methods of selection. This implies that, for the services and activities outsourced, there are

[13] Phelps et al. (2003).

at least two vendors competing to provide the service. Thus, there is at least, in theory, scope for the shipyards to employ both subcontractors should the need arise. However, there are two major problems in assuming that the choice of subcontractor will lead to an automatic source of additional labour.

First, many of the local service subcontractors have the same individual labourers on their workforce rolls. Because the nature of their business is unpredictable, subcontractors are not always able to employ an exclusive set of workers. Thus, Worker A may work for Scaffolder B one week and for Scaffolder C the next, even if both companies are working on similar jobs in the same shipyard. This has the effect of artificially inflating the pool of available subcontract labour. The Shipbuilders and Shiprepairers Association reports the example of a UK shipyard that subcontracts its blasting, painting, and coating work. Although the yard competes the work among four different subcontractors, the workers who actually do the work rotate between companies, depending on which firm has the current contract. The effect: There are only enough workers to fully staff one or two subcontractors rather than the four companies that exist on paper.

Second, many subcontractors that compete for work in one yard may also perform work in another shipyard or local industry. This means that UK warship yards in certain parts of the country may be competing with one another for subcontracted services. This model works well when neither yard is forced to operate beyond capacity. However, should the level of work increase greatly across multiple shipyards at the same time, there is no guarantee that the subcontractor will be available. This is also true when dealing with subcontractors that perform work across various industries. If, for example, a painting subcontractor receives a large contract to work for a construction company, it may be difficult for a shipbuilder to rely on that subcontractor on demand.

However, while it appears that the number of shipbuilding service subcontractors in the United Kingdom is limited, the pool is reasonably mobile. Again, this is difficult to quantify, but conversations with many of the United Kingdom's regional development

agencies[14] indicate that subcontractors are willing to move to another region to perform work if the fee is appropriate and there are prospects for longer-term work. This mobility decreases if a subcontractor also works for a number of non-shipbuilding companies in an area.

The northeast of England appears to have the strongest subcontracting base in the United Kingdom. This is due to a number of factors. First, there are a number of smaller shipyards, repair yards, and offshore fabricators in the northeast. Each of them subcontracts to a varying extent so that there is a steady demand for marine subcontracted services. Second, the northeast has a long history of shipbuilding. This means that the worker skills exist in the area to provide trained labour for local subcontractors. Finally, the Northeast Development Agency, One NorthEast, supports a number of programmes that encourage the formation of marine clusters and interaction between shipyards and subcontractors. There is a northeast marine cluster operated by One NorthEast and supported by the local government, shipyards, trade unions, and academics. The northeast also has a number of local organisations concerned with job and skill preservation, such as the Tyne and Wear Learning Skills Council and the Jobs on the Riverside Project. It is important to note that all of the regional development agencies have similar programmes and agencies charged to develop and maintain core shipbuilding skills.[15] However, because of its emphasis on developing marine clusters, the northeast of England has the deepest marine subcontracting base among UK shipbuilding regions.

Another important marine cluster in the northeast is NEMOC, which is a partnership of 15 northeast companies with ties to the shipbuilding or offshore industry. It is supported by a number of

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[14] During the course of the research, we interacted with the Scottish Enterprise, One NorthEast, and Furness Enterprise. These are the regional development agencies responsible for the areas of the country where traditional shipbuilding industries exist. Most of the information they provided dealt with the quantity and availability of ex-shipyard workers. They provided minimal information on actual subcontracting firms. We received most of our specific information on firms from the shipyards themselves.

[15] Examples of these include Furness Enterprise in the northwest of England, the Clyde Shipyards Task Force in Scotland, and Vosper Thornycroft's 'Skills for Life' programme.

northeast organisations, including the GMB Union, Government Office for the North East, One NorthEast, and the Tees Valley Development Company. NEMOC has structured itself into a loose federation of organisations that can call upon each other's expertise if needed. Its skill range reaches from steel construction and preparation to architectural outfitting to ship and offshore construction. Swan Hunter (one of the two marine construction companies in the cluster) has used NEMOC extensively to subcontract much of its shipbuilding work. Table 2.1 gives an example of the types of firms that belong to NEMOC.[16]

Clusters such as NEMOC provide a subcontracting resource that shipyards can call upon when facing labour gaps in a variety of skill sets. Although it is not formalised to the extent of NEMOC, the potential for cluster-like development also exists in the southeast of England, where both Vosper Thornycroft and Fleet Support Limited (FSL) may require subcontracted skills. The northwest and Scotland would find cluster development difficult because of the lack of major

Table 2.1
Firms That Are Part of NEMOC

Discipline	Companies
Steel construction/preparation	Cleveland Group
	Tyneside Preparation Cluster
Logistics and project services	Shepherd Offshore Services
	SMP Services
Integrated logistics support	Sir Joseph Ischerwoods
Design and engineering	ATA (Armstrong Technology)
Painting and corrosion protection	Barrier
Marine and offshore construction	Swan Hunter Group
	A&P Tyne
Architectural outfitting	C&D Group
HVAC	Chieftain Group PLC
Electrical and instrumentation	Imtech Marine & Industry

[16] One NorthEast (2002, p. 60).

shipyards in the area other than BAE Systems. In fact, a recent study by Scottish Enterprise concluded that the once-existing shipbuilding cluster in the Glasgow area had largely disappeared and that chances of a full reemergence were slim.[17]

Specialised subcontracting firms are only one solution to a labour shortage. There are several additional potential sources of labour that the MOD may also want to consider. They include the following:

- **Other shipyards in the United Kingdom.** Should a particular UK warship builder experience a labour shortfall, the possibility exists to subcontract portions of the work—not to local specialist firms but to other shipbuilders in the United Kingdom that may have excess capacity to undertake appropriate portions of the work.
- **Ex-shipyard workers.** These include former shipyard workers who are currently unemployed, working in other industries, or are on UK incapacity (sickness) benefits.
- **Overseas sources of labour.** In an extreme case, this may imply sending work out of the United Kingdom.[18] However, there are many UK expatriates working in overseas shipyards who may be willing to return to the United Kingdom. Additional sources are EU nationals (who have the right to work in the United Kingdom) and non-EU nationals, assuming they can gain appropriate government work permits.

Use of Smaller Shipbuilders

Another way for UK warship yards to deal with labour shortages is to subcontract the work to other shipyards instead of subcontracting to specialist companies. The advantages to this approach are that it

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[17] Macdougall et al. (2003).

[18] The option of building portions of UK warships outside the country is contrary to current MOD policy that 'all new warship hulls should be fabricated and assembled in UK shipyards'. Letter from Lord Bach, Minister for Defence Procurement, to Furness Enterprise, 25 April 2003.

could help maintain shipbuilding skills within the UK industrial base and could potentially fill gaps in other shipyards' order books. It is also a way to get back on schedule should unforeseen delays affect a ship's construction. Disadvantages of outsourcing to other shipyards include the potential loss of quality control and giving another yard a piece of work when it may not have the technical skills or physical infrastructure to complete it.

This approach already occurs to some extent in the United Kingdom. When Swan Hunter fell behind on the LSD(A) landing craft, it subcontracted a portion of the work to McNulty, an offshore fabrication company on the banks of the Tyne. This allowed Swan Hunter to complete that phase of the LSD(A) build on schedule. Vosper Thornycroft also has adopted this approach. The company established a relationship with Appledore shipbuilders in which it has subcontracted the construction of two hydrographic survey vessels to Appledore.[19] Now that Vosper Thornycroft has moved to the new Portsmouth Naval Base, it is also exploring ways of levelling work with FSL.[20] Thus, each of the two companies will be prepared to 'subcontract' any excess labour it possesses should the other experience a skill shortage. At the time of writing, this programme has not been implemented but shows promise to more efficiently use the available labour force in the Portsmouth area.

The maritime cluster in the northeast of England also is receptive to sharing excess work with local ship and offshore yards. There is a collection of five fabricators in the Newcastle region that have varying degrees of the skills necessary for warship construction. In addition to its own workforce of around 1,000 workers, Swan Hunter would, in theory, have access to an additional capacity of 7,000

[19] Other examples of shipbuilders subcontracting structural work to other shipyards include DML subcontracting the construction of luxury yacht hulls to Appledore and BAE Systems Naval Ships subcontracting tank units for their auxiliary oiler programme to Harland and Wolff.

[20] FSL is partially owned by Vosper Thornycroft.

labourers who are employed by its neighbouring companies.[21] By having this excess capacity to utilise, Swan Hunter is able to mitigate the risks associated with potential labour shortages.

Even though it is not yet common practice among UK shipyards to 'subcontract' work to other UK shipbuilders, the possibility does suggest one solution of how to deal with a labour shortage in a particular shipyard.[22]

Unemployed and Incapacity Roles

In addition to subcontracting work to specialist firms or other shipyards, UK warship builders may also consider expanding the size of their own workforce when faced with a labour shortfall. The UK shipbuilding industry has contracted considerably in the past 20 years, so there may be former workers who are available to be rehired should the need arise. For example, the number of shipyard workers in Barrow has fallen from 14,400 in 1991 to a projected 3,100 by the end of 2003—a reduction of more than 11,000 workers.[23]

When workers are released from a shipyard, they retire, take other jobs (either in another industry or within shipbuilding but at another location), or start taking government benefits (unemployment or incapacity benefits). Research conducted by Sheffield Hallam University in 1999 suggests that when shipyards lay off workers, about 20 percent leave the area and find alternative careers, 20 percent become unemployed, and 50 percent either retire or take sickness benefit.[24] Thus, once these workers have been let go, up to 70

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[21] It is important to note that these are maximum capacity estimations only and not actual employment figures. It is also not meant to imply that Swan Hunter and the other shipyards in the northeast would be able to recruit the additional workers needed to meet a potential demand. The estimation for regional capacity came from One NorthEast and Swan Hunter. One NorthEast (2002, p. 27).

[22] Again, this may not be the best way to deal with the problem, but it is a potential solution.

[23] Furness Enterprise Ltd. (2003, pp. 3, 29).

[24] Furness Enterprise Ltd. (2003, p. 20).

percent of them leave the industry and become unavailable[25] for rehire by their former employer. This agrees very well with a comment by a senior US shipyard executive who said '. . . one lesson we have all learned in the past is that once highly skilled technicians . . . leave our workforce, they do not come back'.[26] Convincing these former workers to return to the shipbuilding industry may be a formidable task.

However, the evidence suggests that a pool of available workers does exist in shipbuilding communities. June 2003 data show 83,959 unemployed workers in the towns surrounding the major UK warship build and repair yards.[27] Table 2.2 shows the breakdown of those figures.[28]

Although all of these unemployed workers would not have the skills or the motivation to work in UK shipyards, there clearly is some

Table 2.2
Unemployed Workers in Various UK Geographic Areas

Town	Unemployed	Yard Nearby
Barrow	1,566	BAE Systems
Dunfermline	3,175	Rosyth
Glasgow	31,462	BAE Systems
Plymouth	5,121	DML
Portsmouth	5,532	Vosper, FSL
Southampton	5,601	Vosper
Sunderland	9,033	Swan Hunter
Tyneside	22,469	Swan Hunter
Total	**83,959**	

[25] Or, at least, very difficult to regain.

[26] Testimony of Jerry St. Pe', Chief Operating Officer of Northrop Grumman Ship Systems, to a US Senate subcommittee on 4 April 2001. The lack of a competitive pay scale may be one reason it is difficult to bring workers back into the shipbuilding industry once they leave.

[27] For the purposes of these data, the major UK warship yards concerned are BAE Systems (Barrow and the Clyde), Swan Hunter, Vosper Thornycroft, Babcock BES (Rosyth), DML, and FSL.

[28] Furness Enterprise Ltd. (2003, p. 30).

scope for shipyards to recruit workers from this pool of labour. For example, One NorthEast estimates that there may be as many as 1,300 skilled shipyard workers and up to 10,000 skilled craft workers in the northeast alone to fill any labour shortfall.[29]

Another labour pool that may be available to shipyards is comprised of former workers who currently receive UK incapacity benefits. Employees are eligible for these benefits if they have exhausted their sick pay entitlements but have been 'incapable' of work because of sickness or disability. Many former shipyard workers were eligible to opt for incapacity benefits (which were more generous) in lieu of unemployment payments when the shipyards downsized because of the physical, demanding nature of their former jobs. These former workers may be considered 'hidden unemployed', since they do not appear on unemployment statistics but are not working.[30] Scottish Enterprise estimates that there are 90,000 workers on incapacity benefits in the Glasgow area alone; of these, 30–40 percent may be physically able to take some position within a shipyard. Although the percentage of incapacity beneficiaries may not be as high in other shipbuilding areas, the pool still represents a substantial source for future workers.

The challenge to the shipyards is to convince these former workers to leave their incapacity benefit and return to work. There are two parts to addressing this challenge. First, worker pay must be sufficient to overcome the 'cost of not working'. Information gathered from regional development agencies and recruitment agencies suggests that workers will only come back into the workforce if salaries in excess of £14,000 per year are available.[31] Since the average skilled manual labour shipyard worker makes between £18,000 and £20,000 per year, this should not be a major obstacle. Second, potential shipyard workers must see a long-term future in their employment. They will

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[29] One NorthEast (2002, p. 50).

[30] Incapacity beneficiaries do not appear on unemployment rolls, since they have a sickness or disability that may prevent them from working. Once individuals on incapacity benefits return to the workforce, their incapacity benefits cease.

[31] Furness Enterprise Ltd. (2003, p. 20).

be hesitant to forfeit their 'incapacity benefit' if they feel they would be back on the unemployment roles after a short period—since they would then only receive general unemployment benefits instead of the more generous incapacity benefit. Current naval procurement plans could be used as a strong justification to allay these fears.

It is important to realise that warship yards will be competing with other projects for these two labour pools. There are a number of projects in both shipbuilding regions and the larger United Kingdom that also have demands for many of the same skills that the shipyards may be looking for. Examples of such projects are the West-Coast Rail electrification project, the planned construction of Terminal 5 at Heathrow Airport, a major housing construction project in Glasgow, and refurbishment of aging UK power plants. Although this list is not intended to be definitive, it shows that the industry should not take the existing labour pool for granted.

A final concern regarding recruitment of skilled workers currently not in the UK shipyard workforce is their age profile. Data collected by the Sector Skills Council for Science, Engineering, and Manufacturing Technologies Alliance (SEMTA) suggest that the UK shipbuilding skills base is aging. Figure 2.8 breaks down the marine skilled workforce by age.[32]

With 33 percent of the workforce aged 50 years or older and another third between the ages of 40 and 50, it is clear that much of the UK shipbuilding workforce will be retiring in the next 10–15 years—in the midst of the largest shipbuilding programme in decades. These retirements not only will decrease the numbers of current shipyard workers but will also diminish the available pool of ex-shipyard workers as they also reach retirement age. This aging population is an issue that will need to be addressed in all regions of the United Kingdom, although it appears to affect the northeast of England worse than the northwest, as Table 2.3 shows.[33]

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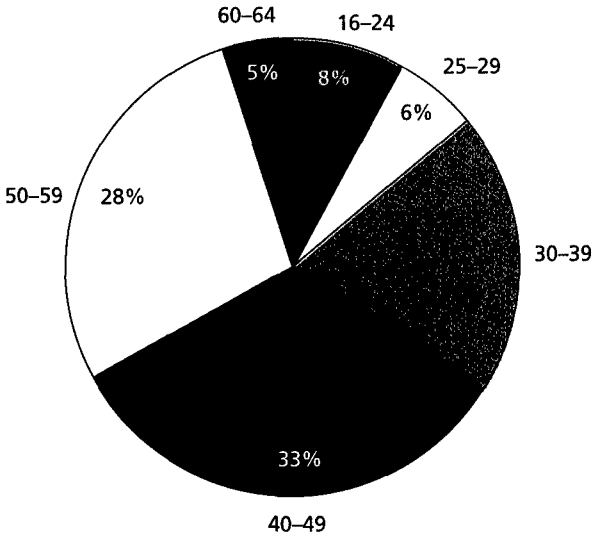
[32] SEMTA, *Marine, Engineering, and Offshore Fabrication Skills Database Report*, Spring/Summer 2003.

[33] Data taken from SEMTA database.

Figure 2.8
Age Distribution of UK Shipbuilding Labour Force



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Projections from One NorthEast support the assertion that up to 40 percent of the northeast's marine workforce will retire by 2015. However, this is an aggregate figure, with retirement projections for specific skills varying somewhat.[34]

Overseas Shipbuilding Labour Pool

A final source of labour for UK shipyards is that of overseas workers. This pool includes UK expatriates working in foreign countries, EU nationals with shipbuilding skills, and non-EU nationals who may have the skills to work on major shipbuilding programmes. There are a number of UK nationals who work in Europe's shipbuilding indus-

[34] One NorthEast (2002, p. 51).

Table 2.3
UK Workforce Distribution by Age

	Age of Marine Worker					
Region	**16–24**	**25–29**	**30–39**	**40–49**	**50+**	**Total**
Northeast	4.5	4.4	14.6	36.4	40.0	100.0
Northwest	8.4	6.4	30.0	28.6	26.6	100.0
Scotland	9.1	5.1	20.2	34.9	30.8	100.0
Southeast	10.7	10.9	14.0	27.5	36.9	100.0
Southwest	7.4	5.9	19.6	35.3	31.9	100.0

NOTE: Due to rounding, some regions' age categories do not add exactly to 100 percent.

try outside the United Kingdom. Many of these workers were originally employed by UK yards but were made redundant and found shipbuilding work abroad. Others have been lured by the higher wages typically paid by shipyards on the Continent, which pose a financial disincentive for them to return to UK shipyards. Nonetheless, anecdotal evidence suggests that, because of family and cultural ties, many of these workers would be receptive to returning to the United Kingdom to work as long as there was promise of long-term stability.

EU nationals are eligible to work in UK shipyards in positions that do not require security clearances. Legally, French, German, or Spanish workers could move to the United Kingdom to take up shipbuilding positions in UK yards. However, there are several obstacles that shipyards may have to overcome to recruit these workers, including language barriers, lower UK wages, cultural incompatibilities, and family separations. Overall, this does not appear to be a viable option, but one that may be utilised as a last resort.

Should UK shipyards have difficulty finding workers within the UK or in Continental Europe, there may also be the possibility of bringing in workers from outside the United Kingdom. There is precedent to grant foreign workers UK work permits should a labour shortage in a particular skill occur. Information technology specialists from India and Eastern Europe obtain permits to work in the United

Kingdom; the same is true for nurses from Australia and New Zealand. However, for the United Kingdom to issue work permits for non-EU workers, the government must conclusively demonstrate that there is a skills shortage. Thus far, this has not happened and would most likely be opposed by trade unions and others. Of the three options for recruiting overseas workers, this is the least likely to occur in the current environment.

Thus, the UK warship yards have a variety of options when looking at how to fill a potential labour shortage. Using subcontract labour may fill some skill shortfalls. However, since the subcontracting labour base is difficult to quantify and appears to be shallow in most regions of the country except for the northeast of England, shipyards may need to look to other shipyards, non-shipyard workers, or overseas sources to fill their labour demands.

Implications to the CVF and Other MOD Shipbuilding Programmes

Our surveys of UK, US, EU, and Asian shipyards suggest that there are two basic total outsourcing models in shipbuilding. At one extreme, shipyards maintain in-house capabilities to accomplish most, if not all, functional tasks. Almost all UK, US, and Asian shipbuilders fall into this class of vertically integrated shipbuilders, although Japanese shipyards use subcontractors when demand for certain tasks exceeds their in-house capabilities. At the other extreme, shipyards maintain basic ship construction capabilities and outsource the majority of outfitting related tasks. Swan Hunter in the United Kingdom, Kvaerner Philadelphia in the United States, and almost all EU shipbuilders fall into this paradigm. In addition to completely relying on subcontractors for certain tasks, these shipyards turn to subcontractors when demands exceed capacity for tasks in which they have maintained in-house capabilities.

Our surveys also suggest that cost savings are not the primary reason shipbuilders use total outsourcing. Although the cost of outsourcing may be slightly less than the cost of maintaining capabilities

in-house, shipyards that use total outsourcing do so mainly to control their workforce in the face of cyclical demands for certain skills. Tough labour policies in certain countries make it difficult and costly to adjust the workforce to meet varying demands. In addition to better workforce management, shipbuilders that use total outsourcing believe the quality of the end product is better with subcontractors that specialise in certain areas, such as accommodations.

Two general messages emerge from the research: (1) one size does not fit all when it comes to total outsourcing, and (2) do not expect total outsourcing to result in significant cost savings. In terms of total outsourcing, the CVF and other MOD shipbuilding programmes should allow shipbuilders to follow their current practices. Having said that, these programmes should encourage shipyards to use subcontractors when demands exceed in-house capacity, as is likely to be the case over the next decade for UK shipbuilders. Temporary labour may also help to meet increased demands, but it may involve higher costs and lower productivity than would qualified subcontractors.

The above recommendation is especially true for structural tasks. All UK shipbuilders have the capability to produce quality structural steelwork. We suggest that the builders of the super blocks consider using lower-tier shipyards, such as Ferguson, to supply some structural components during periods when demands exceed capacity.

Builders of the super blocks should also maintain their total outsourcing practices for electrical and pipe work tasks. Again, other than Swan Hunter—which currently relies on a subcontractor for electrical work—the UK shipyards have in-house capabilities that can be used to meet at least a portion of the demands in future years. These shipyards will need to turn to subcontractors when demands exceed in-house capabilities, but the lower-tier shipyards can also provide some support, especially in producing totally outfitted blocks for the major shipyards.

The one area where the CVF programme should consider total outsourcing encompasses accommodation and personnel support functions, such as cabins, common areas (e.g., meeting rooms and dining facilities), and galleys. These 'hotel' functions are an area

where many UK shipbuilders are starting to turn to subcontractors. For example, a subcontractor will build all the cabins for the Type 45 programme. It is also an area where a subcontractor can produce higher-quality products at lower costs than a shipyard. Finally, common advanced outfitting practices for cruise ships (see the next chapter) typically install cabins and outfit common areas after the ship has been assembled. Although much of this work may be completed on the super blocks that are sent to the final assembly shipyard, a significant portion may need to be done at the final assembly yard.

There are three necessary steps to using total outsourcing for the hotel functions. First, applicable subcontractors must be identified. The subcontractor supporting the Type 45 programme is certainly one option, although there is the question of suitable capacity given the overlap between the Type 45 and CVF programmes. Other alternatives include EU subcontractors, especially those that support the cruise-ship builders in Finland, Italy, France, and Germany. Once a list of suitable subcontractors has been identified, the second issue is whether they can adequately support the multiple shipyards involved in the CVF programme. More than one subcontractor may be required to support the demands of the programme. The third step is that the subcontractors should be involved in the design process as early as possible, especially in regards to dimensions and utility demands and supplies.

One other important consideration resulted from our research—the successful use of subcontractors requires nearly complete production designs and standards and well-planned manufacturing processes that incorporate the use of subcontractors. This not only allows shipbuilders time to adequately prepare for using subcontractors but also gives the subcontractors sufficient time to complete their own planning. This is especially true for systems that cross the super blocks, which will be built in different shipyards. Each shipyard, and all the subcontractors supporting the shipyards, must be working from common designs and standards to ensure that the super blocks match perfectly during the process of assembling the ship.

CHAPTER THREE

Advanced Outfitting Practices and Implications for the CVF

In Chapter Two, we described in overarching terms the degrees to which shipbuilders in the United Kingdom, United States, European Union, and Asia use outsourcing to construct ships. In this chapter, we analyse how those manufacturers currently use *advanced outfitting*, and we evaluate the potential impact of employing higher levels of this technique in their construction processes.

The following five questions guided our examination:

- What degree of advanced outfitting is currently used by UK shipbuilders?
- How do UK outfitting practices compare with those of US and EU shipbuilders?
- What hinders shipbuilders in incorporating higher levels of advanced outfitting?
- What data are available to measure the cost and time impact of different levels of advanced outfitting?
- What level of advanced outfitting is practical for the CVF programme, and should it vary by shipbuilder?

In this chapter, we report the results of our analysis of these questions. After first describing modern ship construction processes and advanced outfitting, we compare how they are practised among UK, US, and EU shipyards. We go on to describe the factors that limit the ability of shipyards to do higher levels of advanced outfit-

ting. We then describe the cost impact of advanced outfitting and, finally, the implications of the research for the CVF programme.

As was the case in Chapter Two, our analysis in this chapter was driven by a survey that we conducted of various shipbuilders in the United Kingdom, United States, and European Union. The survey asked both quantitative and qualitative questions about the level of advanced outfitting for various functional tasks that are typically accomplished at various stages of construction.[1] It queried the shipbuilders on how much outfitting they perform at each stage of the construction process and the cost or time required to perform the outfitting tasks. It also asked about the factors that limit the ability to do more advanced outfitting. Upon receiving the completed surveys, we visited each shipyard to ensure that we had completely understood the responses.

Overview of Ship Construction Processes

Building ships involves two basic activities: constructing structural components of the ship, and outfitting the ship by installing various systems and equipment that allow it to operate and perform various missions.

Modern ship construction techniques involve building ships in pieces or modules. Structural units or assemblies are joined together to form larger pieces that are typically referred to as blocks. Blocks are then combined into still larger pieces, typically called grand blocks or rings, which are lifted into the dry dock or onto the building way or land-level facility and connected to form the complete ship. Definitions of the pieces that make up a ship are the following:[2]

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[1] The advanced outfitting survey form is provided in Appendix B.

[2] Different shipbuilders use different terms for the various pieces that are formed during ship construction. The lowest-level structural units are also called assemblies or modules. Grand blocks are sometimes referred to as super lifts. There are also differences related to the size of the piece. For example, what some shipbuilders refer to as blocks may be called grand blocks by other shipbuilders. These differences in terminology caused shipbuilders some problems in responding to the survey and in turn gave us some problems in analysing their responses.

- **Structural unit.** A three-dimensional structural assembly whose dimensions are usually driven by the maximum plate or panel line size that has all welding complete and contains varying degrees of outfitting.
- **Block.** A structural part of the ship's hull consisting of plates and reinforcing frames, generally produced by erecting and joining panels, assemblies, subassemblies, units, and parts together. This piece can be erected on the ship as a block or combined with other blocks and units to form a grand block.
- **Grand block.** An assembly of blocks that may be built in a fabrication facility or on an outside platen area. Grand blocks usually involve large capacity cranes or transporters to move and lift them into the assembly dock, shipway, or land-level facility.[3]
- **Packaged unit or module.** A grouping of outfit items installed on a common foundation, such as a machinery packaged unit or piping unit, prior to installation on a block, grand block, or assembled ship.
- **Assembled ship.** The joining of blocks and grand blocks to form the 'complete' ship, typically done in a dry dock, shipway, or land-level facility.

Outfitting tasks occur either during the construction of the pieces that make up the ship or once those pieces are assembled to form the completed ship. Outfitting covers a broad range of functional tasks:

- **Structural**—installing equipment foundations, doors, ladders, hatches, and windows
- **Piping**—installing and welding pipes, including spools and connectors

[3] Ships may also be constructed from super blocks, which are large portions of a ship's hull or a deckhouse made up from blocks and grand blocks. The Type 45 and CVF programmes plan on building their ships from several large super blocks constructed at various shipyards and transported to and assembled at one shipyard.

- **Electrical power distribution**—installing the power distribution system downstream of the main power switchboards, including hanging and pulling cables and installing local switchboards and ancillary electrical equipment
- **HVAC**—installing air handling units, ducting, and other ancillary HVAC equipment
- **Joinery**—installing accommodations such as cabins or berths, dining facilities, food preparation areas, and rooms for meetings or other administrative purposes
- **Painting and insulation**—covering the structure and accommodations of the ship.

For naval combatants, outfitting would also include the installation of combat and weapon systems.

Outfitting tasks can take place at several stages in the construction process. Some outfitting must be done during the building of the structural units or blocks, since it would be very difficult, and expensive, to do those tasks later in the construction process. An example is installing pipe work in double-bottom sections of tanker ships, which could not feasibly be done after the sections are built. This is referred to as pre-outfitting, and the practice has a long history dating back to the high levels of shipbuilding during World War II.

Other outfitting tasks can occur at any of the various stages of the construction process. Advanced outfitting involves performing those outfitting tasks early in the ship construction process—i.e., at the unit, block, or grand block stages. Advanced outfitting allows the outfitting tasks to be accomplished in covered production facilities or on nearby staging areas where the materials and equipment are close at hand and where the workforce and construction units are protected from the adverse effects of weather. Also, performing outfitting tasks in production facilities allows the structural elements to be positioned in the best way to allow easier installation of materials and equipment.

Outfitting that occurs at the assembled ship stage requires workers to move to the dry dock, shipway, or land-level facility, bringing with them the materials and equipment and their construction tools.

This adds to the indirect time required to perform a construction task. Installing outfitting materials and equipment is also more difficult and time-consuming on the assembled ship because of the obstructions from structural components or the need to work in confined spaces. Although used to some degree by all shipbuilders, it is the Japanese shipbuilders that have perfected advanced outfitting techniques.

Advanced outfitting reduces the labour time and cost to build a ship. Often, rules of thumb are quoted, such as '1-3-5-10', indicating the number of hours to perform a given task at the unit stage ('1'), the block stage ('3'), the grand block stage ('5'), or on the assembled ship ('10'). The format of these rules of thumb can vary among shipbuilders. For example, some shipbuilders may have only three metrics in their rules—for block, grand block, and on assembled ship. Other shipbuilders will add a metric for ships that have been launched as compared with assembled ships in a dock or land-level facility. Regardless of the format or the specific metrics within a format, all shipbuilders commonly believe there are savings from advanced outfitting. However, little published data exist to measure the actual time and cost impact.

In addition to reducing labour hours, shipyards may strive for higher levels of advanced outfitting to lessen the time spent in constrained facilities during ship construction. For example, at many shipyards the erection dock is the bottleneck in the sequential construction of ships. Reducing the time a specific ship spends in the dock allows the shipbuilder to begin the construction of follow ships sooner. Transferring outfitting hours to the shops or to the assembly areas alongside the dock reduces the hours spent in the dock, thus enabling higher capacity utilisation and, therefore, higher productivity, even if there is no overall reduction in the number of hours to build a ship.

Higher levels of advanced outfitting during construction of the CVF could not only reduce the construction costs of the carriers but could help the programme overcome the potential shortage of labour capacity in the UK shipbuilding industrial base because of the simultaneous demands of several programmes. Recognising these advan-

tages, the CVF IPT has set a goal of each super block being at least 80 percent outfitted and tested by the time it leaves the construction shipyards. However, there is uncertainty regarding the degree of advanced outfitting currently used by UK shipbuilders and whether this goal is achievable.

Current Use of Advanced Outfitting by UK, US, and EU Shipbuilders

The survey that we circulated to shipbuilders was a crucial tool in addressing the first two outsourcing questions that we pursued. However, it proved to be a challenge to find consistent, comparable survey responses from all of the shipyards.

Although the UK, US, and EU shipbuilders were very cooperative, there were problems with how they responded to some of the survey questions requesting quantitative data on the degree and cost of advanced outfitting at various stages on the construction process. Some defined the stages of construction differently from the framework that we provided in the surveys. Their management and production processes were structured somewhat differently, and their data collection systems were not organised to collect the data in the format we had requested. We tried to understand these differences during our shipyard interviews and correct for them in our data analysis. In some cases, we could not convert the data provided to a form that allowed consistent analysis with the majority of the data.

In a few instances, shipyards provided advanced outfitting data that were estimates, as opposed to actual values for specific ship construction programmes. These estimates were based either on goals that had not historically been achieved or on actual values from previous programmes modified to reflect new processes, facilities, or production resources. We did not include these estimates in our analysis.

Finally, some of the shipbuilders, especially those in the highly competitive commercial market, were reluctant to provide detailed data they believed to be business-sensitive or proprietary. They would

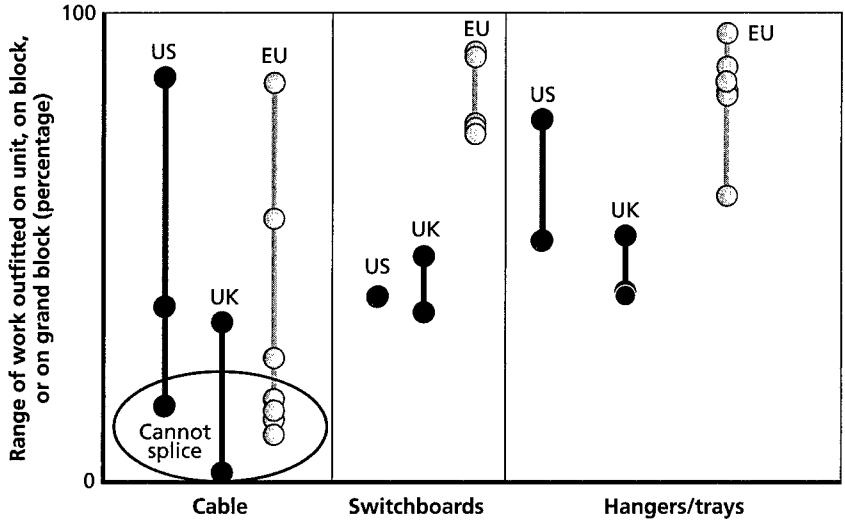
provide and discuss with us their rules of thumb and the rationale behind them, but would not furnish detailed data in the form we requested.

As a result, the database assembled from the shipyard responses is not as robust as we desired, and there is insufficient data for detailed statistical analyses. Nevertheless, the database reveals general trends that allow us to compare the degree of outfitting performed at each construction stage and the cost impact of advanced outfitting.

Electrical Power Distribution Outfitting

The degree of advanced outfitting for the electrical power distribution tasks of installing cable, switchboards, and hangers or trays is shown in Figure 3.1 for different UK, US, and EU shipyards. The vertical axis measures the percentage of the outfitting task accomplished at the unit, block, or grand block stages of construction (i.e., the percentage not accomplished on the assembled ship). The points in the figure represent a specific shipyard's practices and are con-

Figure 3.1
Advanced Outfitting Practices—Electrical Power Distribution



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nected to represent ranges in each task for the UK, US, and EU shipbuilders.

The data suggest that UK shipbuilders accomplish lower levels of advanced outfitting in the three electrical power distribution tasks than do most shipbuilders in the United States or European Union. The figure also suggests that it is reasonable to plan for at least 80 percent advanced outfitting (i.e., before the work is to be done on the assembled ship).

The oval in Figure 3.1 represents shipyards where the customer will not allow cable splicing. In those cases, the main cables were installed on the completed ship.[4] Interestingly, one shipyard that could splice cable did not believe that installing cable early in the construction process was less expensive but rather allowed other outfitting tasks, such as installing HVAC ducts or doing joinery work, to be accomplished earlier and more efficiently.

HVAC and Piping Outfitting

Figure 3.2 shows the degree of advanced outfitting for various UK, US, and EU shipyards for the HVAC tasks (installing ducting and installing HVAC equipment) and piping tasks (installing feet of pipe and installing spools or connectors). The data imply that UK shipbuilders lag behind most US and EU shipbuilders in using advanced outfitting practices for HVAC and piping tasks. They also suggest that 80 percent outfitting by the super block stage is a reasonable goal for the CVF programme; in fact, some shipyards install almost all HVAC ducting and equipment and pipe work by the grand block stage. The one US shipyard in the oval at the bottom right-hand corner of the figure installs all piping at the grand block level and then uses spools and connectors to join the pipe work as grand blocks are placed in the dry dock.

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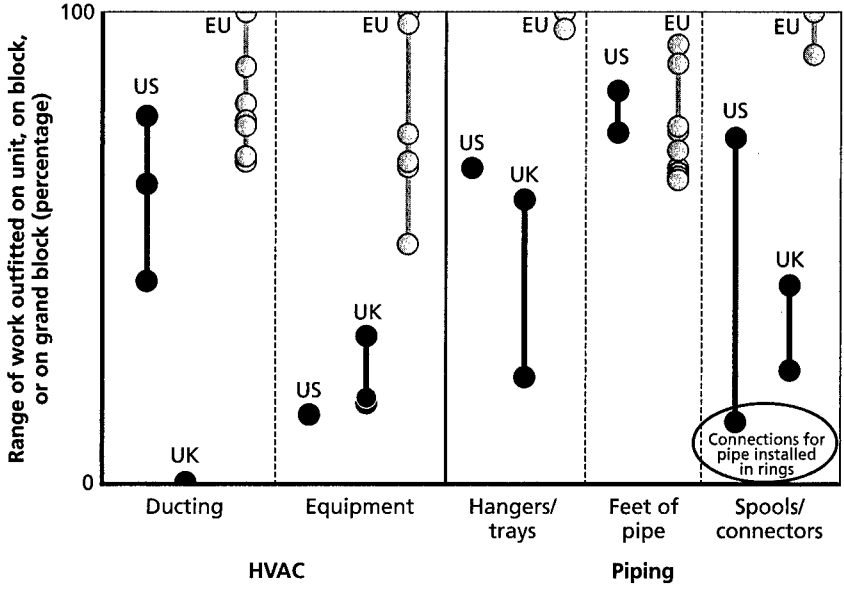
[4] Some shipyards would coil and install cable at the grand block stage and then pull it through connecting portions of the ship.

Figure 3.2
Advanced Outfitting Practices—HVAC and Piping



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Joinery Tasks Outfitting

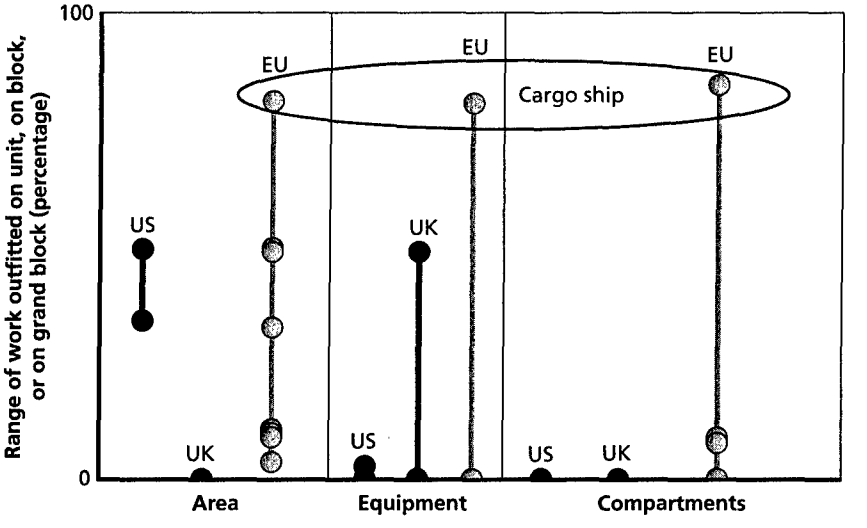
Figure 3.3 shows the degree of advanced outfitting by UK, US, and EU shipyards for joinery tasks measured by square feet of area completed, percentage of equipment installed, and number of compartments completed. Unlike electrical power distribution, HVAC, and piping, it is not obvious that UK shipbuilders do less, or more, advanced outfitting in joinery tasks than the average US or EU shipyard does.

The data in the figure represent two very different cases of joinery outfitting. The EU shipyards in the oval, all of which build cargo or tanker ships, illustrate the first case. The joinery work—i.e., the cabins, galleys, and common rooms—are primarily located in the large deckhouse of the ship. Shipbuilders construct these deckhouses as grand blocks, fully outfitted, and lift them onto the assembled ship

in the dry dock. Swan Hunter has used this technique in the construction of its LSD(A) ships.

The several points in the figure that suggest all outfitting is done on the assembled ship represent the second case. These points represent either cruise ships or military ships. For cruise ships, cabins arrive at the shipyard from subcontractors as complete units and are installed on the assembled ship. Also, specialised subcontractors outfit common areas (e.g., theatres, dining rooms, casinos) once the ship is constructed. Builders of military ships are beginning to adopt these cruise-ship practices for joinery tasks; for example, the Type 45 and CVF programmes are planning to use modular cabins built by subcontractors. The points suggesting very little advanced outfitting also represent the fact that joinery work may be damaged if installed too early in the construction process.

Figure 3.3
Advanced Outfitting Practices—Joinery



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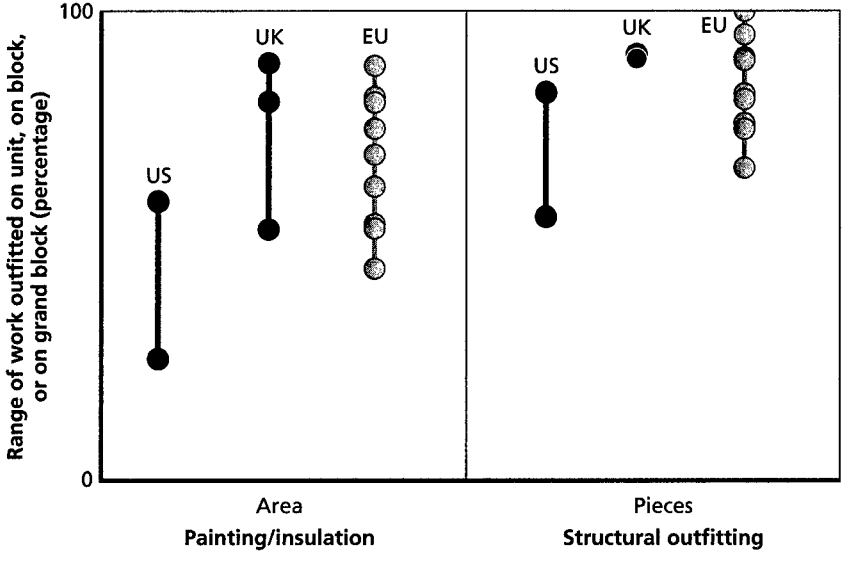
Painting and Insulation, and Structural Outfitting

Figure 3.4 shows the degree of advanced outfitting accomplished by UK, US, and EU shipyards for painting and insulation, and structural outfitting tasks. For these tasks, the advanced outfitting practices at UK shipyards are comparable to those of US and EU shipbuilders. The data also suggest that an 80 percent advanced outfitting goal for painting, insulation, and structural outfitting tasks is reasonable.

During our discussions with UK shipbuilders, they all agreed that higher levels of advanced outfitting were possible, and all were striving to improve their production processes to increase the level of advanced outfitting. The shipbuilders also believed that advance outfitting would reduce the cost and time to build a ship. The shipbuilders involved in the Type 45 programme were planning on a level of

Figure 3.4
Advanced Outfitting Practices—Painting and Insulation, and Structural Outfitting



RAND *MG198-3.4*

80 percent outfitting for the sections of the ship they were building. Based on practices at US, and especially EU, shipyards, this goal can be achievable. Of importance is the proper advanced planning and aligning of management and production processes to accomplish more outfitting prior to the grand block stage.

Limitations to Higher Levels of Advanced Outfitting

In addition to measuring shipbuilders' current outfitting practices, we wanted to understand what factors limited higher levels of advanced outfitting. Potential constraints to greater levels of advanced outfitting included

- lack of timely design information
- lack of outfitting materials or equipment
- concern for damage
- limitations imposed by the customer
- lack of experience in achieving higher levels of advanced outfitting
- facility constraints.

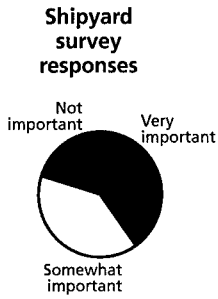
We asked shipbuilders about these potential constraints in our survey. We summarise their responses in Figure 3.5.

Almost all shipbuilders believe the lack of timely design information adversely affects their production planning and management process as well as the degree of advanced outfitting they can accomplish.[5] Most also feel that delays in delivery of outfitting materials and equipment, caused by either incomplete designs or delayed contracting for long-lead items, limit their ability to accomplish higher

[5] Some US shipyards are involved in long production runs in which basic designs are well established.

Figure 3.5
Factors That Limit Higher Levels of Advanced Outfitting

Factors Limiting Outfitting	UK	US	EU
Lack of timely design information			
Lack of materials			
Concern for damage			
Customer limitations			
Lack of experience			
Facility constraints			
Number of shipyards responding	7	3	6



RAND *MG198-3.5*

levels of advanced outfit. Concern for damage of outfit equipment, especially in the joinery area, is a factor, particularly for UK shipbuilders. UK shipbuilders also cited limitations imposed by the customer as a major factor limiting the degree of advanced outfitting they could accomplish. During our interviews, the time required to resolve questions or issues on the clarification of requirements that arose during the construction of the ship was typically mentioned in this area. Along the same lines, UK shipbuilders felt that it was often difficult to get resolution on such questions and issues when multiple MOD groups were involved in the decision process. The inability to splice cable was one construction-related customer limitation mentioned.

Surprisingly, in their survey responses, most shipyards did not feel facility constraints were a limiting factor. However, during our on-site interviews, officials often mentioned the lack of capacity of cranes to lift grand blocks into the dry dock or the lack of platen space to install advanced outfitting into the grand blocks as practical limitations to the degree of advanced outfitting that could be accomplished.

The Cost Impact of Different Levels of Advanced Outfitting

To understand the potential cost impact of higher levels of advanced outfitting, we performed a literature review and included questions in our surveys sent to the various shipyards. There are many reports and journal articles that discuss the advantages of advanced outfitting, but few provide quantitative data of specific applications.

One journal article described the success of a Canadian shipyard in building mid-sized bulk carriers in the early 1980s.[6] One noticeable advantage of advanced outfitting was an increase in the state of completion of the ships at launch from the dry dock. The completion of accommodations was raised by 15 percent (from 30 to 45 percent), of pipe work by 20 percent (from 55 to 75 percent), of machinery by 15 percent (from 60 to 75 percent), and of electrical by 15 percent (from 30 to 45 percent).

The shipyard also realised a significant decrease in total labour hours as a result of the change in advanced outfitting practices. Hours to complete the engine room were decreased by 20 to 40 percent for different outfitting tasks, and the hours to complete the superstructure were reduced by 30 to 40 percent, again depending on the specific outfitting task.

A second, unpublished report suggested a US shipbuilder had reductions of 25 percent in painting tasks, 33 percent in machinery installation, and 50 percent in pipe work as a result of increased use of advanced outfitting.[7]

The shipyard survey forms included questions seeking quantitative data on the degree of outfitting accomplished in different functional areas at various stages of ship construction and the hours (or cost) expended on those functions at each stage. We hoped these data would allow us to more accurately measure the impact on labour hours of higher levels of advanced outfitting. Unfortunately, as men-

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[6] Telfer (1985).

[7] Laurent C. Deschamps, *Productivity in Shipbuilding: Final Report*, SPAR Associates, April 2003 (unpublished report provided to RAND).

tioned previously, the shipbuilders could not or would not provide the requested data for several reasons, including incompatibility of shipyard data collection systems and the reluctance to furnish data believed to be business-sensitive. However, the data they did provide and the insights gained from the on-site interviews clearly suggested that advanced outfitting did reduce labour hours and ship construction times.

A number of EU shipyards did provide the ratio of hours for accomplishing outfitting at different stages of the construction process based on their experience. We show these estimates in Table 3.1. These inputs and others from the survey, in addition to the interviews, provided a wide range of labour hour savings from advanced outfitting. Some of the variability was associated with different functional tasks; some was due to specific shipyard practices; and some was due to the type of ship built by the shipyard. Overall, the data and interviews suggested an approximately 25 percent reduction in total hours when performing outfitting tasks at the block or grand block level compared with performing the same tasks on the assembled ship in the dry dock. The percentage reduction was greater for structural outfitting tasks, pipe work, painting, and insulation, and less for accommodations and electrical work.

There are several observations about the ratios in Table 3.1. First, only Shipyards 1 and 3 considered any advanced outfitting at the unit stage. Most of the data provided considered the block stage as the earliest point for advanced outfitting. In some areas, advanced outfitting tasks began at the grand block level, such as at Shipyards 3 and 4 for joinery tasks and Shipyard 1 for painting and insulation tasks. Second, Shipyard 1 typically did not feel there was any difference in hours between outfitting tasks at the block stage or grand block stage. Shipyard 3 suggested the same hours for painting and insulating tasks if those tasks were complete at the unit, block, or grand block stages of construction. Finally, many of the data points suggest there is little difference in the hours between performing certain outfitting tasks at the block stage compared with doing them at

Table 3.1
Outfitting Factors Provided by EU Shipyards

	On Unit	On Block	On Grand Block	On Assembled Ship
Electrical Power Distribution				
Shipyard 1	1.00	1.20	1.20	1.50
Shipyard 2		1.00	2.00	4.00
Shipyard 3		1.00	1.25	1.50
Shipyard 4		1.00	1.10	1.20
HVAC				
Shipyard 1	1.00	1.20	1.20	1.50
Shipyard 2		1.00	2.00	4.00
Piping				
Shipyard 1	1.00	1.25	1.25	1.50
Shipyard 2		1.00	2.00	4.00
Shipyard 3	1.00	1.00	1.50	2.00
Shipyard 4		1.00	1.10	1.30
Joinery				
Shipyard 2		1.00	2.00	4.00
Shipyard 3			1.00	1.50
Shipyard 4			1.00	1.20
Painting and Insulation				
Shipyard 1			1.00	1.50
Shipyard 2		1.00	2.00	4.00
Shipyard 3	1.00	1.00	1.00	2.00
Shipyard 4		1.00	1.10	1.30
Structural				
Shipyard 1	1.00	1.20	1.20	1.50
Shipyard 2		1.00	2.00	4.00
Shipyard 3	1.00	1.00	1.50	2.00
Shipyard 4		1.00	1.30	1.40

the grand block stage. Certainly these ratios were much less than the '1-3-5-10' rules of thumb often quoted.

Two other issues came from the survey and interviews. One was that all hot work should be completed as early as possible in the construction process—and certainly before painting of the blocks or grand blocks. The second point was that, whenever possible, packaged assemblies and units versus the individual components should be used and installed in the blocks or grand blocks, or even on the assembled ship. For example, machinery units composed of structural foundations, equipment, and all pipe work and electrical work should

be 'packaged' and installed as a complete unit instead of building up the unit on the ship. A second example widely used in the cruise-ship industry and becoming more common in naval warships is the use of completely fabricated cabins and accommodations. These cabins are typically built at a factory, often by subcontractors; sent to the shipyard; and lifted onto the assembled ship as a complete unit. The only shipyard task is to secure the cabin in place and connect the electrical, HVAC, and other utility functions. These modular cabins replace the previous practice of constructing the accommodations with the various parts and components on the ship (although this practice is still used by some UK and US shipbuilders).

As mentioned above, some of the variation in data provided by the shipyards is due to specific practices that shipbuilders have adopted to reduce the time to perform outfitting tasks on the completed ship. For example, one shipbuilder installs external elevators by the ship in the dry dock to reduce the time needed to get workers and materials to the upper decks of the ship. Another shipbuilder packages outfitting materials and equipment in the grand blocks when they are lifted into the dry dock as a way to reduce transit times for outfitting tasks. Finally, one builder of naval combatants designs its ships with higher overheads and wider passages to facilitate the movement of workers and materials as well as to reduce the difficulty in performing outfitting tasks on the assembled ship.

The type of ship under construction affects the potential savings in labour hours associated with higher levels of advanced outfitting (see Table 3.2). Naval combatants (and commercial cruise ships) require much more outfitting, and therefore a larger percentage of the total construction hours devoted to outfitting, than naval auxiliaries (or commercial cargo or tanker vessels). Therefore, greater savings with advanced outfitting are realised on combatants than on auxiliaries.

Naval combatants are also much 'denser' ships than auxiliaries. That is, they are more tightly packed with outfitting equipment and systems compared with auxiliaries, which typically have large open spaces for cargo or liquid storage. This implies that outfitting on the

Table 3.2
Comparisons Between Types of Naval Ships That Affect Advanced Outfitting

	Naval Combatants	Naval Auxiliary
Outfit hours as a percentage of total hours	High	Low
Density	High	Low
Systems	Distributed throughout ship	Concentrated in small area

assembled ship is much more difficult for naval combatants: It is harder to bring materials and equipment onto the assembled ship, and installing these materials and equipment must be done in more confined spaces. Again, higher levels of advanced outfitting will result in larger savings for combatants than on auxiliaries.

Finally, pipe work, electrical systems, HVAC systems, and accommodations and common areas run throughout naval combatants. On auxiliary ships, much of the outfitting work is concentrated in the superstructure of the ship. There is a greater benefit to outfitting the blocks and grand blocks of naval combatants than on naval auxiliaries. In fact, for naval auxiliaries, the superstructure is often built as a large block, completely outfitted, and lifted onto the assembled hull in the dock or by the pier.

The CVFs are not as dense as a surface combatant (or submarine) but are denser than an auxiliary. The ships will require a large number of outfitting hours, and the systems will run throughout the ships. This suggests that high degrees of advanced outfitting offer the potential of significant reductions in total construction labour hours for the CVF programme. The results of our literature review and surveys suggest that savings in outfitting hours on the order of 25 percent are possible if the shipyards alter their current practices and outfit the super blocks to higher degrees.

What Level of Advanced Outfitting Is Practical for the CVF Programme, and Should It Vary by Shipbuilder?

Our research suggests that UK shipbuilders could do higher levels of advanced outfitting in pipe work, electrical, and HVAC functions. US and EU shipbuilders typically outfit their blocks and grand blocks to higher levels in these areas than the current practices of UK shipbuilders. Goals of 80 percent outfit at the super block stage are reasonable and achievable.

Using more finished products than UK shipbuilders typically do can increase the levels of advanced outfitting. This includes packaged machinery units, complex pipe assemblies, and modular cabins and galleys. Using such packaged products can also increase the degree of outsourcing done by UK shipbuilders by having subcontractors produce the items.

Increased levels of advanced outfitting should lead to a reduction in the number of labour hours needed to build the CVF. Although our survey suggests the labour savings are highly variable and depend on several factors, it is reasonable to assume that performing outfitting tasks at the block and grand block levels requires 25 percent fewer labour hours than doing them on the completed ship (or super block) when it is in the dry dock.

The programme must ensure that the proper conditions exist to support higher levels of advanced outfitting. First and foremost, a near-complete, detailed design is necessary before any production work begins so that the shipyards can adequately plan their outfitting activities. This is especially true for systems such as electrical, piping, and HVAC that will cross the super blocks.

The CVF design should both facilitate advanced outfitting during block and grand block construction and reduce the time to install equipment and perform construction tasks on the assembled ship. This will decrease not only the time to build the ships but also the time and effort during refit and repairs.

To complete much of the design before construction, shipyards building the super blocks must be involved in the design process. In the process, shipbuilders are likely to share information and experi-

ence on their outfitting practices, which will allow the best ideas to come forth and, hopefully, be adopted by all shipyards.

Higher degrees of advanced outfitting are also possible through judicious assignment of super blocks. Super blocks that incorporate higher levels of outfitting should be assigned to shipyards that can demonstrate the capability for higher levels of advanced outfitting. Also, as mentioned previously, facility constraints such as lay-down areas and crane limitations can affect the degree of advanced outfitting that is feasible at a shipyard. Shipyards with adequate lay-down areas and heavier crane capacities should be assigned super blocks that would benefit most from higher levels of advanced outfitting.

In addition to needing complete detailed design documentation on the applicable systems and subsystems, the CVF programme requires timely availability of materials and equipment to accomplish higher degrees of advanced outfitting. The programme should ensure that material and equipment purchase orders, especially for long lead-time items, are placed well enough in advance of being needed at the shipyards.

APPENDIX A

Outsourcing Survey

Definitions

Turnkey Outsourcing

Turnkey outsourcing is made up of three distinct parts:

- the design of a system normally done in close coordination with the leading design shipyard or design agent
- the provision of the parts and materials needed to implement the design
- the labour for installation of the system in a ship normally in close coordination with the construction shipyard.

Partial-Turnkey Outsourcing

Partial-turnkey outsourcing is the acquisition of some, but not all, essential elements for some specific ship system. For example, partial-turnkey outsourcing might involve

- the design and parts and materials for a propulsion system that is installed by the shipyard
- materials and painters for painting a ship.

Labour Subcontracting

Labour subcontracting involves hiring temporary labour to perform specific tasks and functions. An example may be hiring temporary labour for painting portions of the ship, with the shipyard providing

the painting materials. The temporary labour is under the control of the shipyard and may work alongside permanent employees.

Table 1: Indicate whether you used outsourcing for any distributed or localised ship system or any functions or tasks within the past several years. For each function or task, indicate the percentage of the total man-hours or cost that is done by turnkey subcontractors, by partial-turnkey subcontractors, by subcontracted labour, or by your own in-house labour and purchased equipment.

Table 1
Extent of Outsourcing as Percentage of Total Effort

Function/Task	Turnkey	Partial Turnkey	Temporary Labour	In-House
Structural blast and prime				
Structural fabrication				
Hull outfit				
Machinery				
Piping				
Electrical power distribution				
HVAC				
Painting				
Accommodations				
Food prep/service				
Common areas				
Combat systems				
Other (please list):				
_____				

Table 2: Use the following scale to indicate the importance of each of the following reasons for outsourcing for each function, task, subsystem, or system that you outsource:

1 = very important
2 = somewhat important
3 = not important.

Table 2
Primary Reasons for Outsourcing

Reason for Outsourcing	Structural Blast and Prime	Structural Fabrication	Hull Outfit	Machinery	Piping	Electrical Power Distribution	HVAC	Painting	Accommo-dations	Food Prep/ Service	Common Areas
Shortage of manpower											
Lack necessary skills											
Lack necessary certification											
Do not want to invest in new technology											
Do not want to invest in new capital											
Capacity constraint											
Schedule constraint											
Corporate directive											
Buyer specified											
Strategic relationship											
Cheaper than in-house (please indicate the percent cost savings from subcontracting versus in-house)											
Other: _____											

Additional Questions

1. If you do not employ turnkey outsourcing or, as we have defined it, partial-turnkey outsourcing, at your shipyard, please explain why. Consider, for example, government restrictions, labour contract restrictions, lack of suitable vendors, and so forth.

2. What percentage of your total cost in delivering a ship is, on average, for outsourcing?
   Turnkey _____
   Partial Turnkey _____
   Temporary Labour _____

3. Have your outsourcing practices changed over the last several years?
   YES _____ NO _____

   If you answered YES, please describe changes and the reasons for the changes.

4. Do you aspire to greater amounts of turnkey or partial-turnkey outsourcing?
   YES _____ NO _____

   If you answered YES, please describe your plans and any potential problems in implementing those plans.

5. Are you developing turnkey or partial-turnkey outsourcing vendors to serve your yard?
   YES _____ NO _____

   If you answered YES, please describe the nature of the outsourcing efforts and the vendor(s) involved.

6. Describe how you determine which subcontractors to use during ship construction. For example:

   Do you typically use the same subcontractor for the majority of your ship projects?
   YES _____ NO _____

   Do you compete outsourcing work among various subcontractors?
   YES _____ NO _____

   If you do use competition, what are the criteria you use to select the winning subcontractor?

7. How do you identify potential subcontractors? For example:

   Do subcontracting firms contact you describing their capabilities?
   YES _____ NO _____

   Are there trade organisations that you interact with to identify potential subcontractors?
   YES _____ NO _____

   If so, what are those organisations?

APPENDIX B

Advanced Outfitting Survey

Definitions

Shipyards may vary in the specific activities included in the outfitting process or may use different terms to describe their activities. To make it possible to compare data from different ships and shipyards, we ask that you use the definitions provided here.

Outfitting Tasks

- **Structural:** Installing equipment foundations, including doors, ladders, hatches, and windows.
- **Piping:** Installing and welding pipes, including spools and connectors.
- **Electrical Power Distribution:** Installing the power distribution system downstream of the main power switchboards, including hanging and pulling cables and installing local switchboards and ancillary electrical equipment.
- **Heating, Ventilation, and Air Conditioning (HVAC):** Installing air handling units, ducting, and other ancillary HVAC equipment.
- **Joinery:** Installing accommodations such as cabins or berths, dining facilities, food preparation areas, and rooms for meetings or other administrative purposes.
- **Painting and Insulation:** Covering the structure and accommodations of the ship.

Stages of Fabrication

- **Unit:** A grouping of outfit items installed on a common foundation, such as a machinery packaged unit or piping unit, prior to installation on a block, grand block, or assembled ship.
- **Block:** A structural part of the ship's hull consisting of plates and reinforcing frames, generally produced by a shipyard panel line. Can be erected on the ship as a block or combined with other blocks and units to form a grand block.
- **Grand Block:** An assembly of blocks that may be built in a fabrication facility or on an outside platen area. Grand blocks usually involve large capacity cranes or transporters to move and lift them into the assembly dock, shipway, or land-level facility.
- **Assembled Ship:** Joining of blocks and grand blocks to form the 'complete' ship, typically done in a dry dock, shipway, or land-level facility.
- **On-Unit Outfitting:** Manufacturing outfitting units, usually in a shop.
- **On-Block Outfitting:** Installing outfit components on a block before it is erected on the building berth or joined to other blocks to form a grand block.
- **On–Grand Block Outfitting:** Installing outfit components on a grand block before it is erected on the building berth or joined to other grand blocks.
- **On-Board Outfitting:** Traditional practice of installing outfit components on board a ship while on the building berth or afloat.

Instructions for Completing Tables

The tables on the following pages ask for data on the level of outfitting and relative productivity at each stage of ship construction. Each table has various units of measurement for the particular outfitting type of function. For example, the table on electrical power distribution has feet of cable installed, number of switchboards installed, and number of hangers or trays installed. We are hoping to understand how much of each unit of measurement (e.g., how much cable) is installed at each phase of ship construction. We have also provided a row in the table for 'other' to capture any unit of measurement for the type of outfitting that is appropriate for your shipyard.

Under each unit of measurement, we ask for the man-hours or cost at that stage of production. For example, how many hours (or cost) did it take to install the cable at the unit stage, the block stage, etc.?

If data are not readily available, please estimate the percentage of each task that is done at each stage. For example, estimate the percentage of cable installed at the unit stage, the block stage, the grand block stage, and on the assembled ship, and the hours to install that cable.

If the man-hour or cost data are unavailable, please estimate the relative investments of time or money at each stage of production. Use *1* for the costs or man-hours of doing the outfitting at the lowest level of installation and indicate the level of investment for each subsequent stage using the lowest level as a basis for comparison. For example, if a certain task (e.g., installing cable) requires three times the investment in time and money at the grand block stage as it does at the block stage, enter a *1* in the block column and a *3* in the grand block column.

If the figures differ for different ships, please complete an additional copy of each table for each ship.

Level of Outfitting and Relative Productivity at Different Stages of Construction

Electrical Power Distribution

Type of Ship	Total	On Unit	On Block	On Grand Block	On Board
Feet of cable installed					
Man-hours or cost					
Number of switchboards installed					
Man-hours or cost					
Number of hangers or trays installed					
Man-hours or cost					
Other:					
Man-hours or cost					

Heating, Ventilation, and Air Conditioning (HVAC)

Type of Ship	Total	On Unit	On Block	On Grand Block	On Board
Feet of ducting installed					
Man-hours or cost					
Number of air handling units installed					
Man-hours or cost					
Number of ancillary equipment installed					
Man-hours or cost					
Other:					
Man-hours or cost					

Piping

Type of Ship	Total	On Unit	On Block	On Grand Block	On Board
Feet of pipe installed					
Man-hours or cost					
Number of spools/ connectors installed					
Man-hours or cost					
Number of hangers or trays installed					
Man-hours or cost					
Other:					
Man-hours or cost					

Joinery Work

Type of Ship	Total	On Unit	On Block	On Grand Block	On Board
Area (square feet) completed					
Man-hours or cost					
Number of pieces of equipment installed					
Man-hours or cost					
Number of compart-ments finished					
Man-hours or cost					
Other:					
Man-hours or cost					

Painting

Type of Ship	Total	On Unit	On Block	On Grand Block	On Board
Area (square feet) completed					
Man-hours or cost					
Gallons applied					
Man-hours or cost					
Other:					
Man-hours or cost					

Structural Outfit

Type of Ship	Total	On Unit	On Block	On Grand Block	On Board
Number of pieces installed					
Man-hours or cost					
Number of fittings installed					
Man-hours or cost					
Other:					
Man-hours or cost					

Additional Questions

1. Have your outfitting practices changed over the last several years?
   YES _____ NO _____

   If you answered YES, what caused the change?

   What were the results of the change?

2. Are you seeking to accomplish different levels of outfitting at each stage of construction for future projects?
   YES _____ NO _____

   If you answered YES, please describe the changes in outfitting practices you hope to implement.

   What benefits do you hope to realise?

3. Early outfit may be damaged during subsequent stages of fabrication. What was your rework rate, in terms of added labour hours required to correct for damaged early outfit in the cited project? (Note that we are concerned only with rework associated with damage, not rework required by design changes.)

4. Early outfitting can be restricted by many factors. Please indicate with a check which of the following factors limit your outfitting practices.

Factors That Limit a Greater Degree of Advanced Outfitting

Limitations to Early Outfitting	Very Important	Somewhat Important	Not Important
Lack of timely design information			
Lack of materials			
Concern for damage to sensitive equipment			
Customer limitations			
Lack of experience			
Facility constraints			
Other (please list):			
_____			

Please identify what, if anything, can be done to correct the constraints you identify.

5. What units are used to measure outfitting progress? For example, do you track number of pieces of equipment and materials installed relative to the total, the man-hours expended relative to the total, or some other parameter(s)?

Please explain how you selected these measures and what other measures have been considered.

6. When is outfitting considered complete in your yard? At the end of construction but before testing? At delivery when all testing is done and deficiencies are satisfied? At some other time?

Bibliography

Altic, Brian E., Richard M. Burns, B. J. Fontaine, Ian Scott, John L. Silveira, and John Softley, 'Implementation of an Improved Outfit Process Model', *Journal of Ship Production*, Vol. 19, No. 1, February 2003, pp. 1–7.

Baade, Ralf, Fiedrich Klinge, Kevin Lynaugh, Frank Woronkowicz, and Klaus-Michael Siedler, 'Modular Outfitting', *Journal of Ship Production*, Vol. 14, No. 3, August 1998, pp. 170–179.

Christensen, Walter L., and Philip Koenig, 'Standard Outfit Package Units in the LPD17 Ship Design: A Production Impact Study', *Journal of Ship Production*, Vol. 11, No. 4, November 1995.

Furness Enterprise Ltd., *Reducing Strains on the Labour Resource Available for Warshipbuilding in the UK*, July 2003.

Jaquith, Peter E., Richard M. Burns, Steve E. Dunbarr, B. J. Fontaine, Harry A. Nelson, John L. Silveira, and Tom D. Thompson, 'Modular Engine Room Design and Construction for the Strategic Sealift Ships', The Society of Naval Architects and Marine Engineers, paper presented at the 1996 Ship Production Symposium, 14–16 February 1996.

Koenig, Philip C., Hitoshi Narita, and Kolchi Baba, 'Strategies and Outcomes in the Two Sectors of the Japanese Shipbuilding Industry', *Journal of Ship Production*, Vol. 17, No. 3, August 2001, pp. 174–182.

_____, 'Shipbuilding Productivity Rates in East Asia', *Journal of Ship Production*, Vol. 19, No. 1, February 2003, pp. 32–37.

_____, 'Shop Floor Automation and Market Strategy in Japanese Shipbuilding', *Journal of Ship Production*, Vol. 19, No. 3, August 2003, pp. 131–140.

Macdougall, Lynne, Andrea Glass, Kevin Higgins, Andy Hirst, Alan McGregor, and Victoria Sutherland, *The Glasgow Challenge: Realising the Potential of Glasgow's Hidden Unemployed*, Glasgow, UK: University of Glasgow, Training and Employment Research Unit, July 2003.

Meland, Kenton, and Rick Spaulding, 'Workload and Labour Resource Planning in a Large Shipyard', *Journal of Ship Production*, Vol. 19, No. 1, February 2003, pp. 38–43.

Moen, Dennis, 'Application of Zone Logic and Outfit Planning Concepts to Overhaul, Modernization, and Repair of U.S. Navy Ships', *Journal of Ship Production*, Vol. 1, No. 4, November 1985, pp. 238–248.

Murphy, Catherine M., 'Increasing Efficiency Through Outfit Planning', *Journal of Ship Production*, Vol. 5, No. 1, February 1989, pp. 1–9.

Nishiguchi, Toshihiro, *Strategic Industrial Sourcing: The Japanese Advantage*, Oxford, UK: Oxford University Press, 1994.

One NorthEast, *A Business Case Supporting the North East of England's Bid for the Future Aircraft Carrier Programme (CVF)*, April 2002.

Phelps, Thomas A., Mitchell Fleischer, Thomas Lamb, and Kevin DeGraw, 'Strategic Outsourcing: A Process for Shipbuilders', *Journal of Ship Production*, Vol. 19, No. 1, February 2003, pp. 16–21.

Sato, Shuji, and Shizuo Suzuki, 'IHI Zone Logic Application to Electrical Outfitting on Highly Sophisticated Ships,' *Journal of Ship Production*, Vol. 6, No. 2, May 1990, pp. 93–100.

SEMTA, *Marine, Engineering, and Offshore Fabrication Skills Database Report*, Spring/Summer 2003.

Telfer, Alan J., 'Zone Outfitting in a Canadian Great Lakes Shipyard: The First Four Years', *Journal of Ship Production*, Vol. 1, No. 4, November 1985, pp. 249–258.